AD NUMBER
AD336996
CLASSIFICATION CHANGES
TO: **unclassified**
FROM: **confidential**
LIMITATION CHANGES
TO: **Approved for public release, distribution unlimited**
FROM: **Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 01 FEB 1963. Other requests shall be referred to Air Force Aeronautics Systems Division, Wright-Patterson AFB, OH 45433.**
AUTHORITY
28 feb 1975 DoDD 5200.10; asd usaf ltr, 12 sep 1975

CONFIDENTIAL

CONFIDENTIAL

336996

BOEING

336 996

This document contains information affecting the National defense of the United States within the meaning of the Espionage Laws, Title 18, U.S.C., Section 793 and 794, its transmission to or the revelation of its contents in any manner to an unauthorized person is prohibited by law.

SEATTLE, WASHINGTON

CONFIDENTIAL

CONFIDENTIAL

THE BOEING COMPANY

NUMBER D2-80911

UNCLASSIFIED TITLE FINAL REPORT DYNA SOAR TESTING FOR THE BOEING COMPANY

MODEL NO. X-20A CONTRACT NO. AF33(657)-7132

ISSUE NO. 10 ISSUED TO AFTIA

CLASSIFIED TITLE
(STATE CLASSIFICATION)

CHARGE NUMBER

2-5142

GROUP 4
DOWNGRADED AT 3 YEAR INTERVALS, DECLASSIFIED AFTER 12 YEARS.
DOD DIR. 5200.10

PREPARED BY

SUPERVISED BY

APPROVED BY

CLASS. & DISTR. APPROVED BY

RELIABILITY APPROVAL

(DATE)

VOL. NO.

PAGES 1-24 PAGE 1 OF

DOCUMENT TITLE PAGE U3 4287 9000 REV. 1 61

CONFIDENTIAL

63RWRS-12112

DOCUMENT DISTRIBUTION

	Number of Copies
NASA, Langley Research Center Langley AFB, Virginia Attention: Mr. P. Korycinski	1
NASA, Ames Research Center Moffett Field, California Attention: Mr. R. Crane	1
NASA, Flight Research Center Edwards AFB, California Attention: Mr. P. F. Bikle	1
Air Force Flight Test Center Edwards AFB, California Attention: FTF	1
Arnold Engineering Development Center Arnold Air Force Station Tullahoma, Tennessee Attention: AEPA	1
Aeronautical Systems Division (ASZRA) Wright-Patterson AFB, Ohio ~~Attention: ASNRP~~	3
AFTIA Arlington Hall Station Arlington, Virginia	10
Air Force Plant Representative Seattle, Washington Attention: RWRSB	1

CONTRACT REQUIREMENT

This document is submitted in compliance with the requirements of paragraphs B(1.1.1.1.1) and B(1.1.3.1.1)1 of the Statement of Work, System 620A, Exhibit 620A-62-2, dated 26 January 1962, revised 1 August 1962.

CONFIDENTIAL

Rhodes and Bloxsom APPLIED PHYSICS RESEARCH

7343 DEERING AVENUE
CANOGA PARK, CALIFORNIA
DIAMOND 0-2707

Feb. 1, 1963

FINAL REPORT
DYNASOAR TESTING FOR THE BOEING COMPANY
UNDER P.O. B-438883-9155
WORK STATEMENT 2-5781-4-129

ABSTRACT:

This report with the models submitted constitutes partial performance under

FINAL REPORT
DYNASOAR TESTING FOR THE BOEING COMPANY
UNDER P.O. B-438883-9155
WORK STATEMENT 2-5781-4-129

ABSTRACT:

This report with the models submitted constitutes partial performance under the above mentioned P.O. and work statement.

This report consists of three parts: 1) deals with the details of data reduction, flow computations and calibrations for the two run configurations, 2) deals with the test log, installation drawings, model photographs and heat transfer distributions obtained, 3) deals with the theory of the paint operation.

APPROVED: D. Bloxsom, Jr

D. Bloxsom, Jr.
Project Engineer
Rhodes and Bloxsom

CONFIDENTIAL

2

D2-80911
3

DYNASOAR TESTING

PART I:

The following runs were made under the conditions listed:

Run #	angle of attack	configuration	dynes/cm^2 $1/2 \rho v^2$	Fin Configuration
1	25°	.04 scale A	97000	6" diameter leading edge, 55° sweep; rudder deflection: left 10°, right 20°; yaw of 3.5° right produces zero yaw left 7.0° yaw right on model
2	20°	.04 scale A	97000	6" diameter, 55° sweep; rudder deflection, 10° left, 20° right; yaw of 3.5° right produces zero yaw left 7.0° right on model
3	20°	.04 scale A	97000	8" diameter leading edge radius, 60° sweep; rudder deflection: left 10°, right 20°; yaw of 3.5° right produces zero yaw left, 7.0° yaw right on model
4	20°	.04 scale B	25,000	6" diameter leading edge, 55° sweep; rudder deflection 10° left 10°, right 20°; yaw of 3.5° right produces zero yaw left, 7.0° yaw right on model

The stagnation conditions were set up by measurement of the capacitor voltage to .5% and the capacitance to 1%. With the known bomb volume (.5%) and the known room temperature and initial bomb pressure (.5%) set up by bourdon and marsh gauges calibrated by dead weight, the stagnation conditions can be computed from air real gas tables for equilibrium by using a 99% efficiency factor of energy conversion from capacitors to air. The validity of the latter assumption may be seen in Figure I, in which 38 previous runs were analyzed by means of measured pressure rise in the stagnation chamber. Late data shown in Figure I has a scatter of 1%, earlier data analyzed for 59 additional runs shown scatter between 75 and 125% efficiencies.

Once the stagnation conditions were known, then the nozzle calibrations were obtained from previous experience as to nozzle velocity and dynamic pressure. These calibrations are enclosed. Dynamic pressure was measured on Run 4. The rest of the nozzle parameters

				rudder reflection, 10° left, 20° right; yaw of 3.5° right produces zero yaw left 7.0° right on model
3	20°	.04 scale A	97000	8" diameter leading edge radius, 60° sweep; rudder deflection: left 10°, right 20°; yaw of 3.5° right produces zero yaw left, 7.0° yaw right on model
4	20°	.04 scale B	25,000	6" diameter leading edge, 55° sweep; rudder deflection 10° left 10°, right 20°; yaw of 3.5° right produces zero yaw left, 7.0° yaw right on model

The stagnation conditions were set up by measurement of the capacitor voltage to .5% and the capacitance to 1%. With the known bomb volume (.5%) and the known room temperature and initial bomb pressure (.5%) set up by bourdon and marsh gauges calibrated by dead weight, the stagnation conditions can be computed from air real gas tables for equilibrium by using a 99% efficiency factor of energy conversion from capacitors to air. The validity of the latter assumption may be seen in Figure 1, in which 38 previous runs were analyzed by means of measured pressure rise in the stagnation chamber. Late data shown in Figure 1 has a scatter of 1%, earlier data analyzed for 59 additional runs shown scatter between 75 and 125% efficiencies.

Once the stagnation conditions were known, then the nozzle calibrations were obtained from previous experience as to nozzle velocity and dynamic pressure. These calibrations are enclosed. Dynamic pressure was measured on Run 4. The rest of the nozzle parameters were obtained from computation from the known frozen flow nozzle parameters.

Once the nozzle parameters were known, the calibration sphere was checked for shock standoff distance to determine flow equilibrium conditions on the calibration sphere. From previous calibrations, the shock standoff distance measured for 5 spheres in 5 runs was .065 R checking the expected shock standoff distance for non-equilibrium nozzle flow and equilibrium sphere flow of .070R (where R is sphere radius).* Hence the flow is in equilibrium on the calibrating spheres. Once this was known the theory of Lees (Jet Propulsion, April 1956 page 259, vol. 26 #4) was used to compute the stagnation rates on the calibration spheres, and the same theory with measured pressure gradient (figure 2) was used to compute rates around the spheres. Spheres of various diameters from 3.00 inches to .250 inches were used to determine the heat transfer rates to be assigned to the various colors. 101 readings of these ratios of heat transfer are plotted in the color curve of part 3). Once these rates were obtained, the same colors were read on the models and surface heat transfer contours developed. These surface heat transfer contours were all referenced to the heat transfee rates expected on the Dynasoar glider at the following conditions:

altitude 250,000 feet (ARDC 1959 model atmosphere)
velocity: 20,000 feet/second

All the developed plots refer to these conditions, but actual rates in the tunnel may be obtained from the scaling factors plotted in configurations A, B.

Due to the short time models were available for reading at the Rhodes and Bloxsom plant, only maximum and calibrations rates were measured and included in this report.

*See figure 3

CONFIDENTIAL

2

DYNASOAR TESTING

CALIBRATIONS FOR CONFIGURATION A

Test section distributions: V_{oo} constant at 15,200 feet/second
Z_{oo} constant at 1.32, effective gamma frozen flow: 1.495
density variations given in Figure 4 (series)
temperature variations vary as square root of density variations (similar to heat transfer variations)

To 8000°K, H_o 2 $\times 10^8$ ft^2/sec.^{2}; P_o 1405 psia; M_{oo} 15.2; T_{oo} 140°K, V_{oo} 15,200 ft/second

rho_{oo} 8.62 x 10^{-7} gm/cm^3; p_{oo} 6.86 x 10^{-3} psia; Re_{oo}/ft. 124,000; Z_{oo} 1.32

where $_c$ conditions are stagnation, $_{oo}$ conditions are tunnel ambient free stream at tunnel nozzle C_L

Additional parameters computed behind normal shock for equilibrium flow heat transfer using Lee's theory: dynamic pressure x 2 equals sphere pressure of .185 atm., density behind ~~sphere~~ shock is 7.6 x 10^{-6} gm. cm^3. Lees theory gives 367 watts/cm^2 for the stagnation point of a 3.00 inch sphere or 523 watts/cm^2 for the stagnation point of a 1.48 ~~inch~~ sphere (ping pong ball). For a Ferri number of 8630 we find an increase vorticity factor of 1.09 for a final rate of 400 watts/cm^2 for the 3.00 inch sphere or 570 watts/cm^2 for the 1.48 inch sphere. The following rates with vorticity hold for the flight rates on the scaled 1.48"diameter/.04 sphere:

Flight rates	scaling factor
31.7 watts/cm^2	.04

CALIBRATIONS FOR CONFIGURATION B

CALIBRATIONS FOR CONFIGURATION A

Test section distributions: V_{oo} constant at 15,200 feet/second
Z_{oo} constant at 1.32, effective gamma frozen flow: 1.495
density variations given in Figure 4 (series)
temperature variations vary as square root of density variations (similar to heat transfer variations)

To 8000°K, H_o 2 $\times 10^8$ ft^2/sec.^{2}; P_o 1405 psia; M_{oo} 15.2; T_{oo} 140°K, V_{oo} 15,200 ft/second

rho$_{oo}$ 8.62 x 10^{-7} gm/cm^3; p_{oo} 6.85 x 10^{-3} psia; Re_{oo}/ft. 124,000; Z_{oo} 1.32

where $_c$ conditions are stagnation, $_{oo}$ conditions are tunnel ambient free stream at tunnel nozzle C_L

Additional parameters computed behind normal shock for equilibrium flow heat transfer using Lee's theory: dynamic pressure x 2 equals sphere pressure of .185 atm., density behind ~~sphere~~ shock is 7.6 x 10^{-6} gm. cm^3. Lees theory gives 367 watts/cm^2 for the stagnation point of a 3.00 inch sphere or 523 watts/cm^2 for the stagnation point of a 1.48 inch sphere (ping pong ball). For a Ferri number of 8630 we find an increase vorticity factor of 1.09 for a final rate of 400 watts/cm^2 for the 3.00 inch sphere or 570 watts/cm^2 for the 1.48 inch sphere. The following rates with vorticity hold for the flight rates on the scaled 1.48" diameter/.04 sphere:

Flight rates	scaling factor
31.7 watts/cm^2	.04

CALIBRATIONS FOR CONFIGURATION B

Test section distributions: V_{oo} constant at 14,500 feet/second
Z_{oo} constant at 1.36, effective gamma frozen flow: 1.495
density variations given in Figure 5
temperature variations similar to Figure 4 heat transfer variations

T_o 7500°K, **P_o** 350 psia, **H_o** 2×10^8 ft^2/sec^2; M_{oo} 15.4, T_{oo} 138°K, V_{oo} 14,500 ft/sec

rho$_{oo}$ 2.55 x 10^{-7} gm/cm^3, P_{oo} 1.37 x10^{-4} atm. ; Re_{oo}/ft. 31,000; Z_{oo} 1.32

Referring the rates to the flight conditions with vorticity we get for the scaled 1.48" diameter/.04 sphere:

Flight rates	scaling factor
31.7 watts/cm^2	.04

Figure 6 gives the theory and calibration of the paint operation (Part 3). 5500 frames/second movies are also included of side view in self luminosity light.

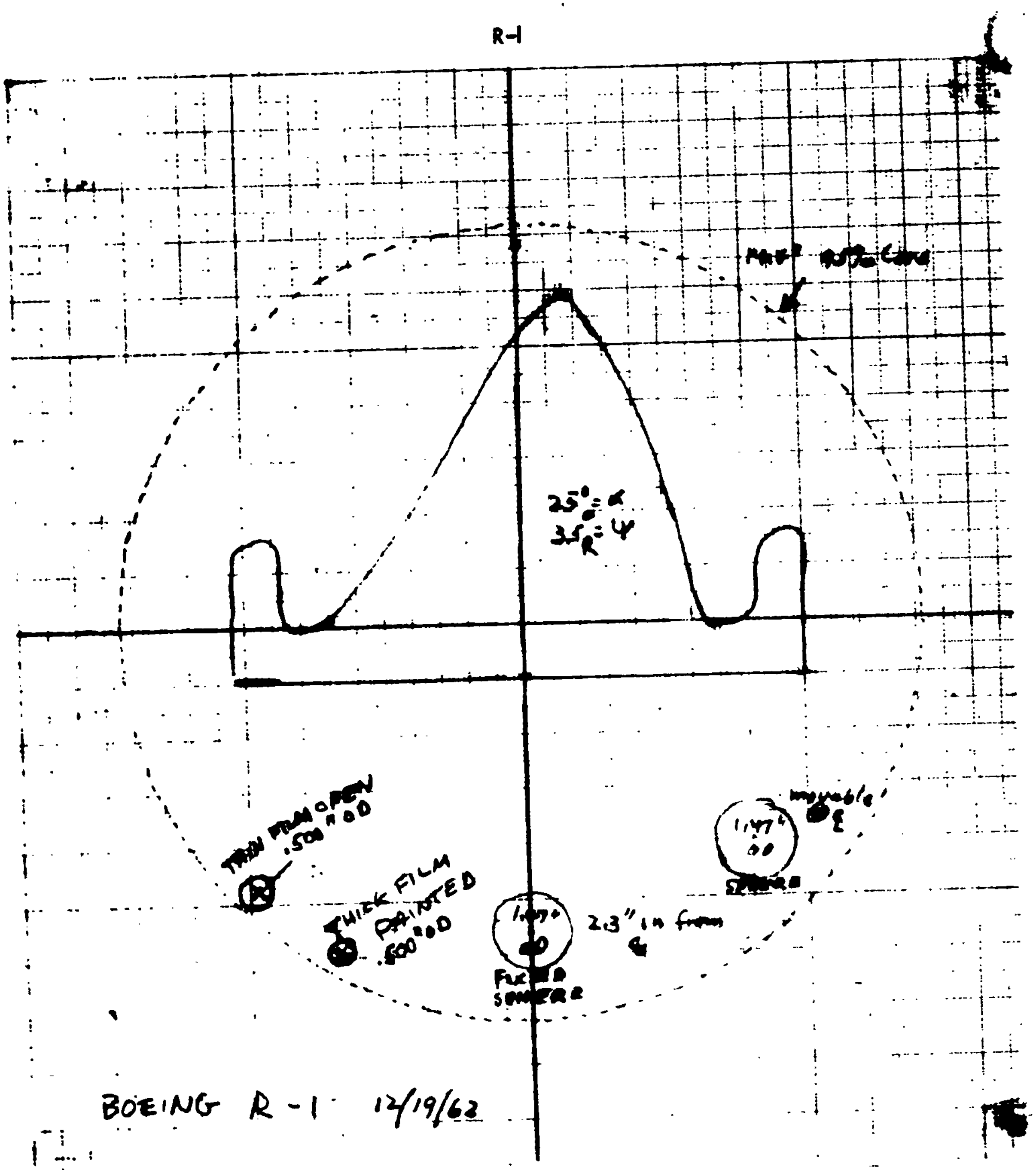
CONFIDENTIAL

2

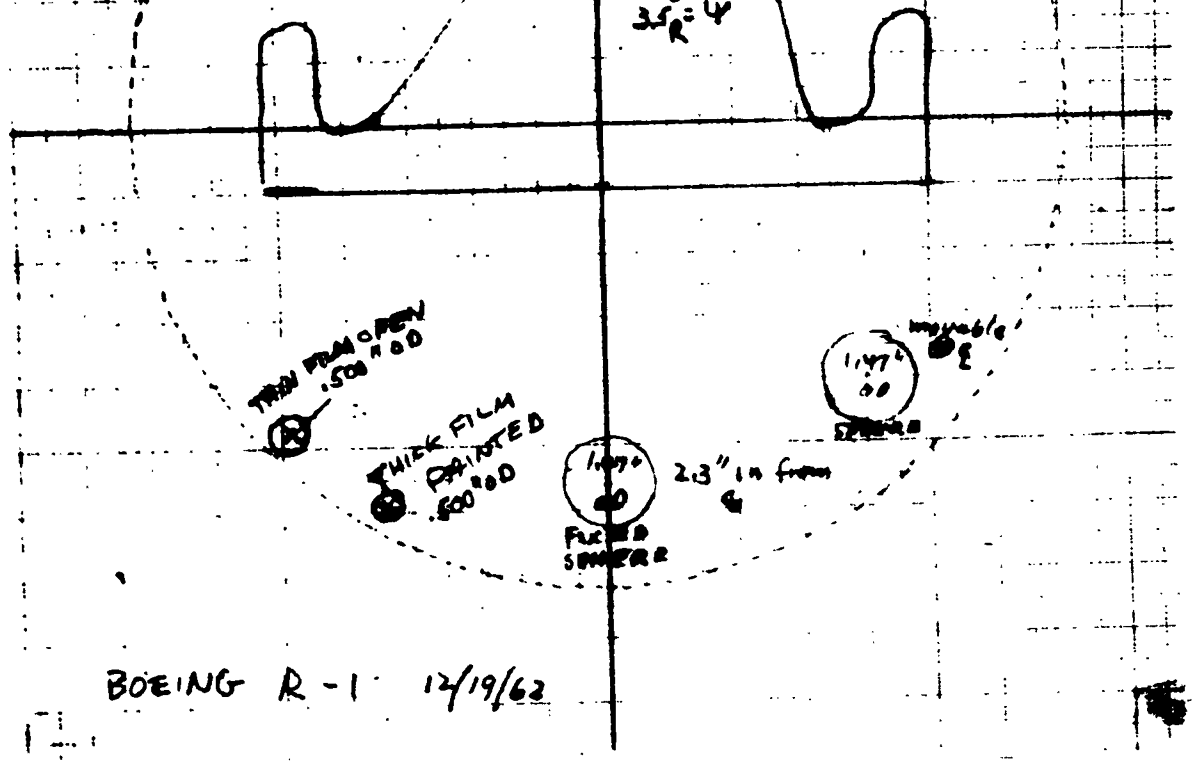
D2-80911
5

CONFIDENTIAL

R-1



1



INSTALLATION DRAWING

MODEL PHOTOGRAPH

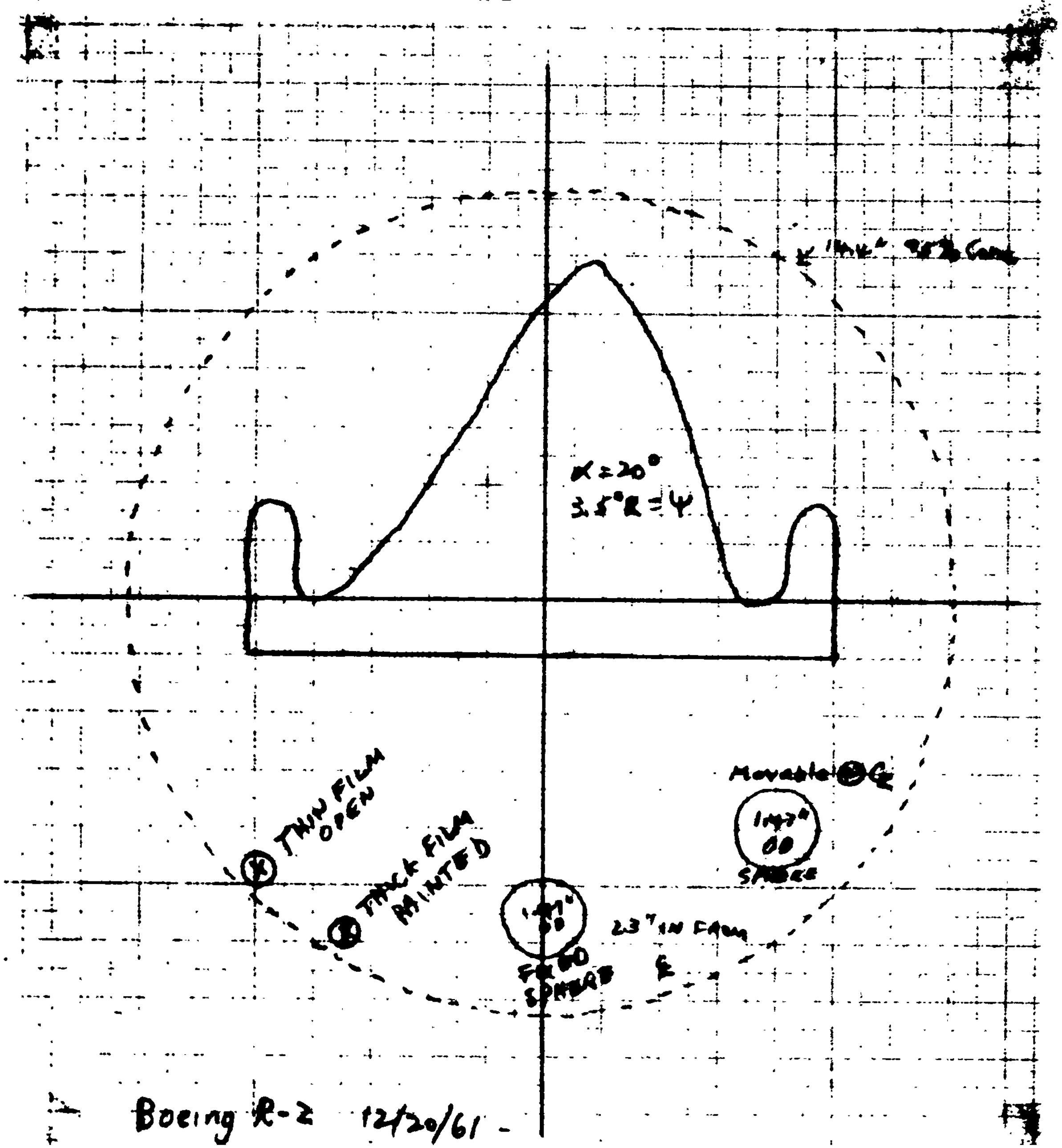
CONFIDENTIAL

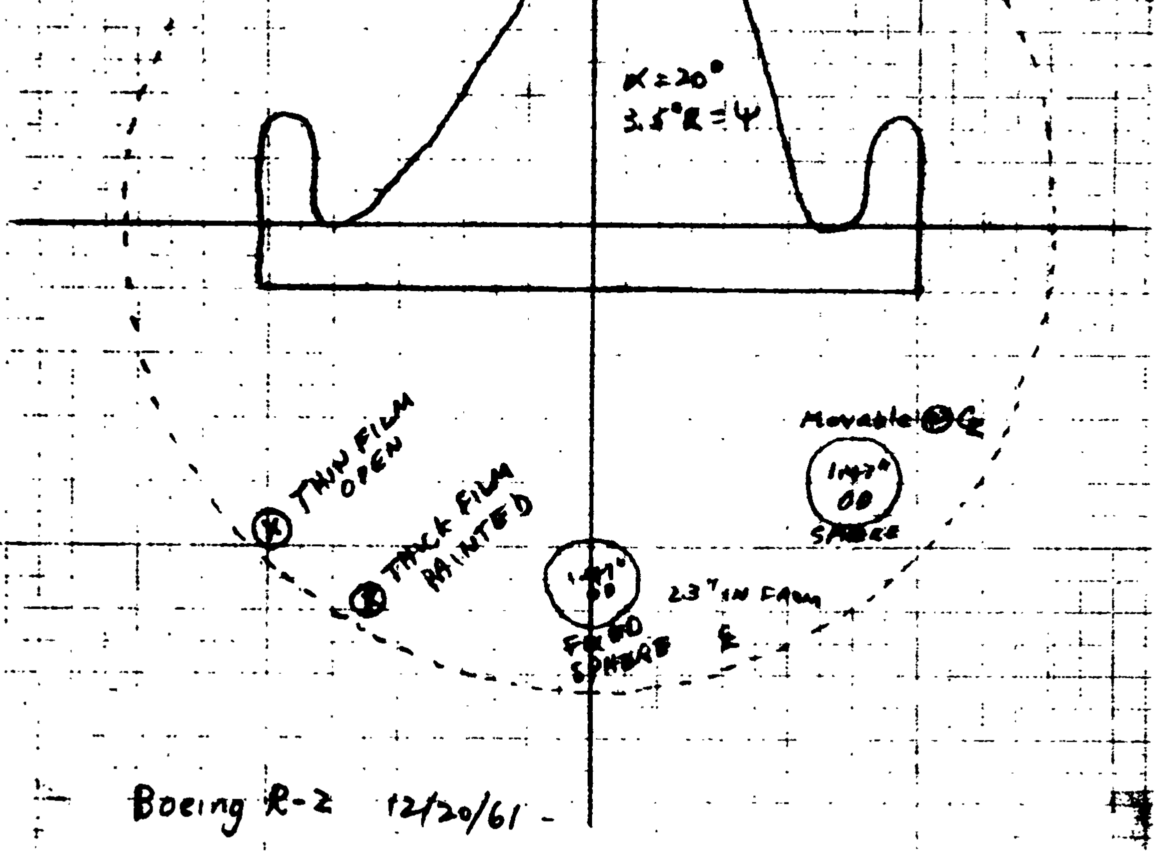
2

D2-80911
6

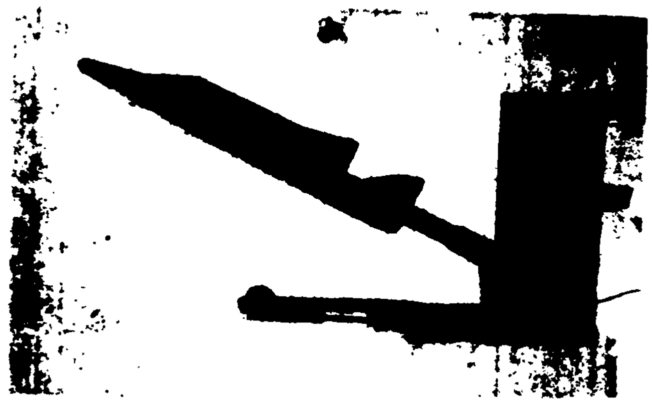
CONFIDENTIAL

R-2





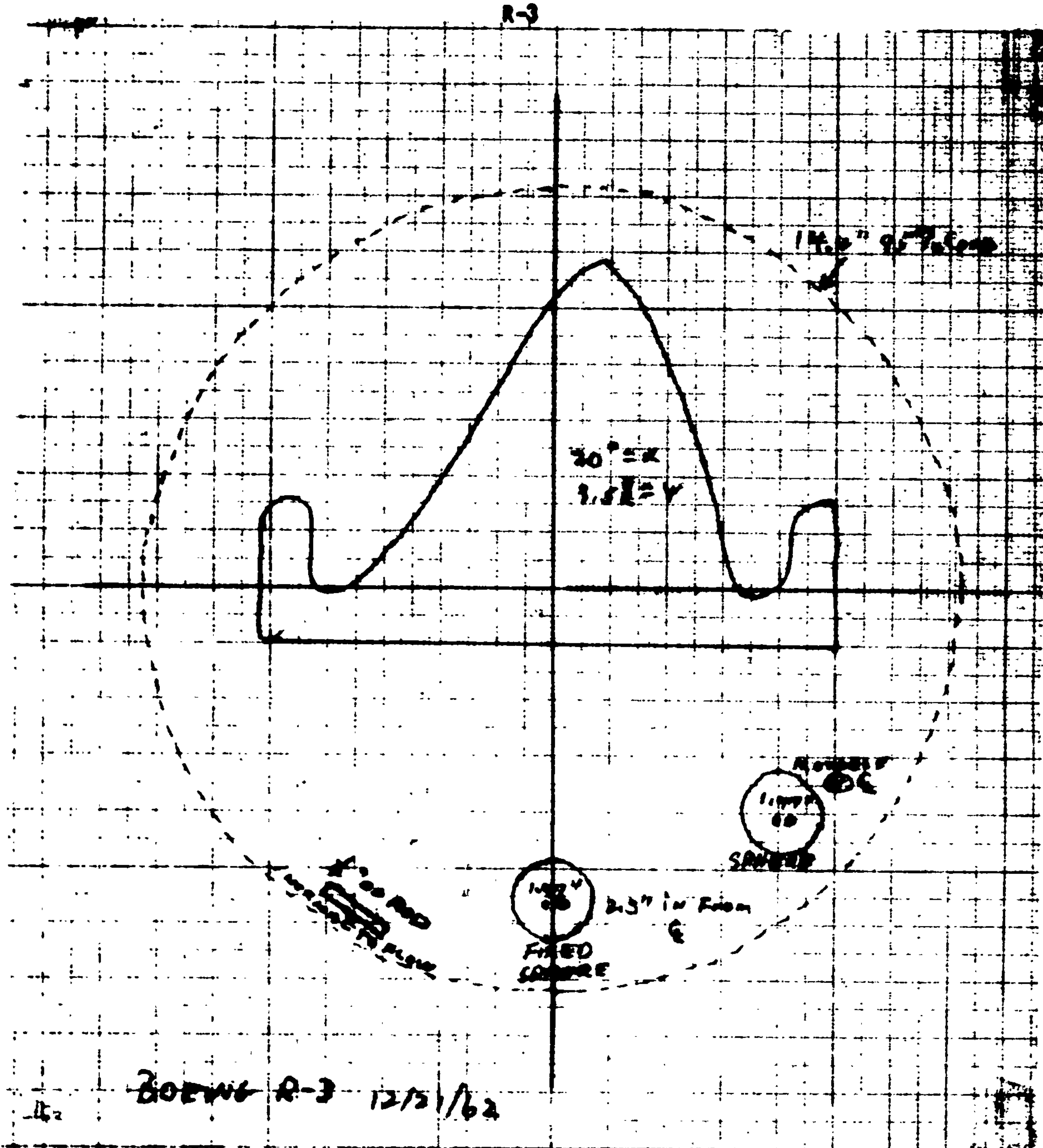
INSTALLATION DRAWING



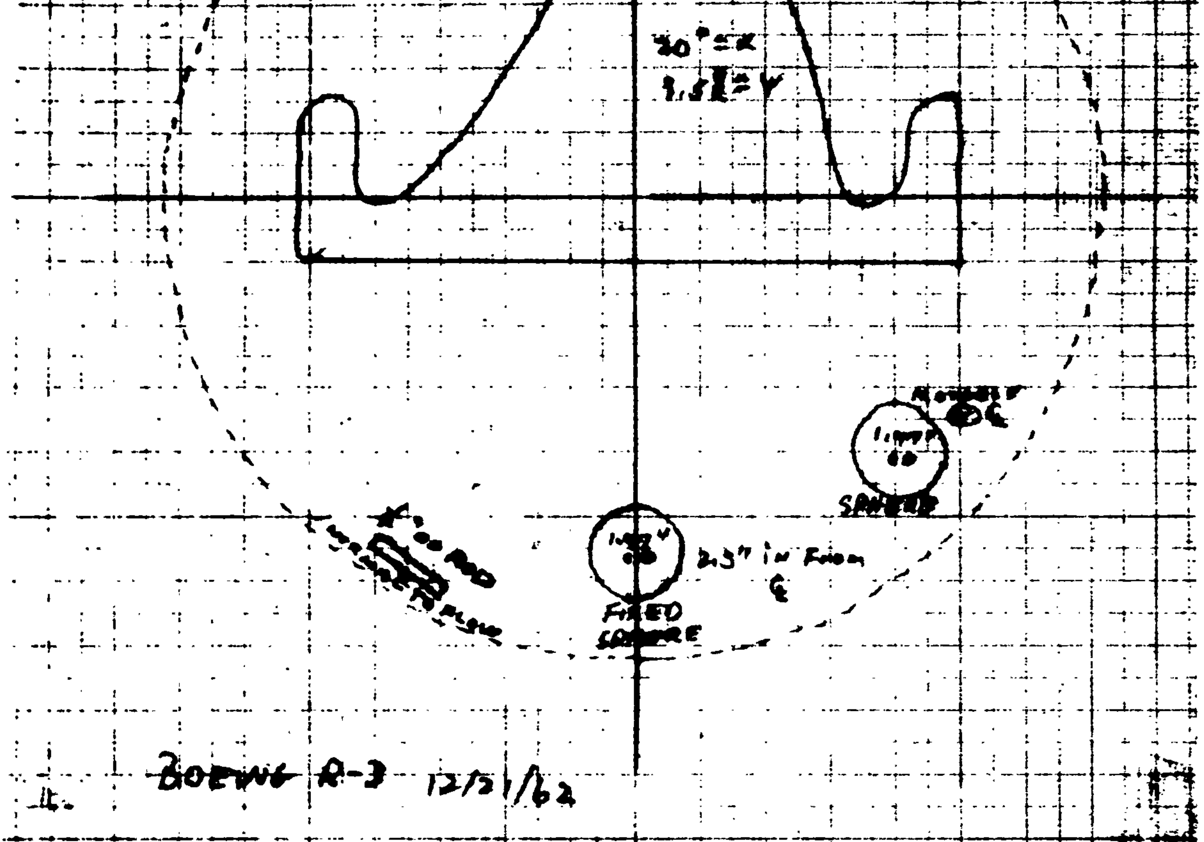
MODEL PHOTOGRAPH

CONFIDENTIAL

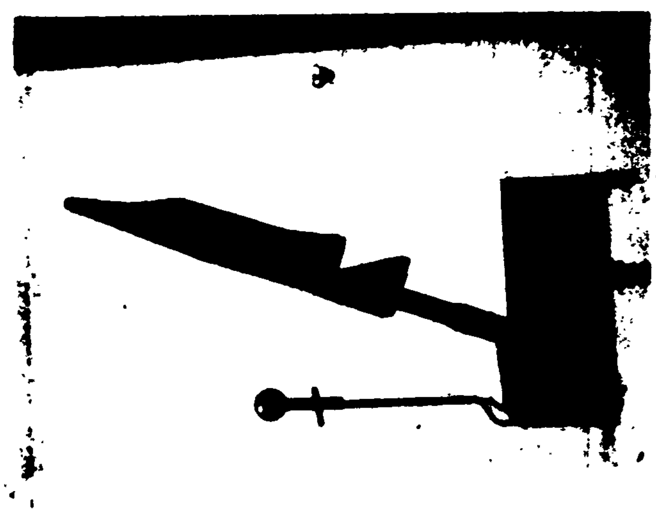
CONFIDENTIAL



INSTALLATION DRAWING



INSTALLATION DRAWING

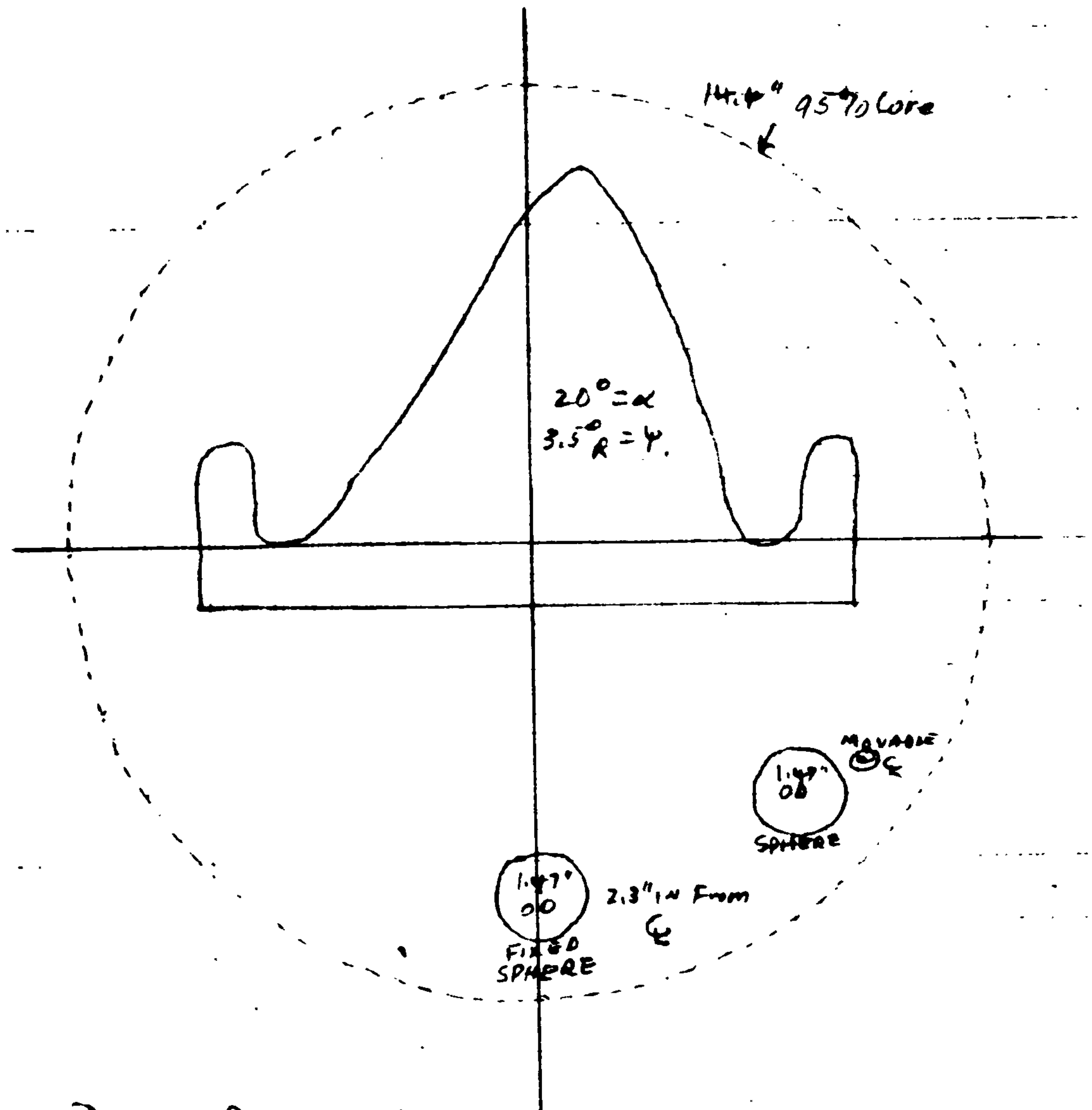


MODEL PHOTOGRAPH

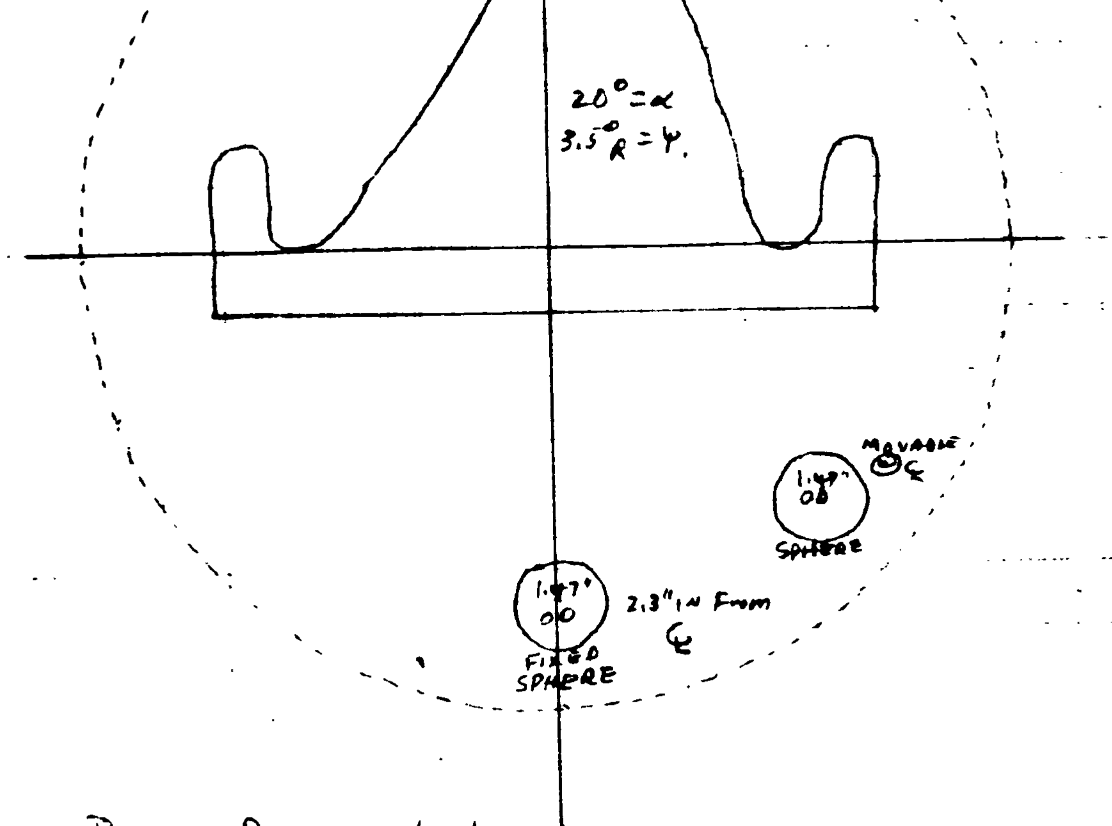
CONFIDENTIAL

CONFIDENTIAL

R-4



Boeing R-4 12/21/62



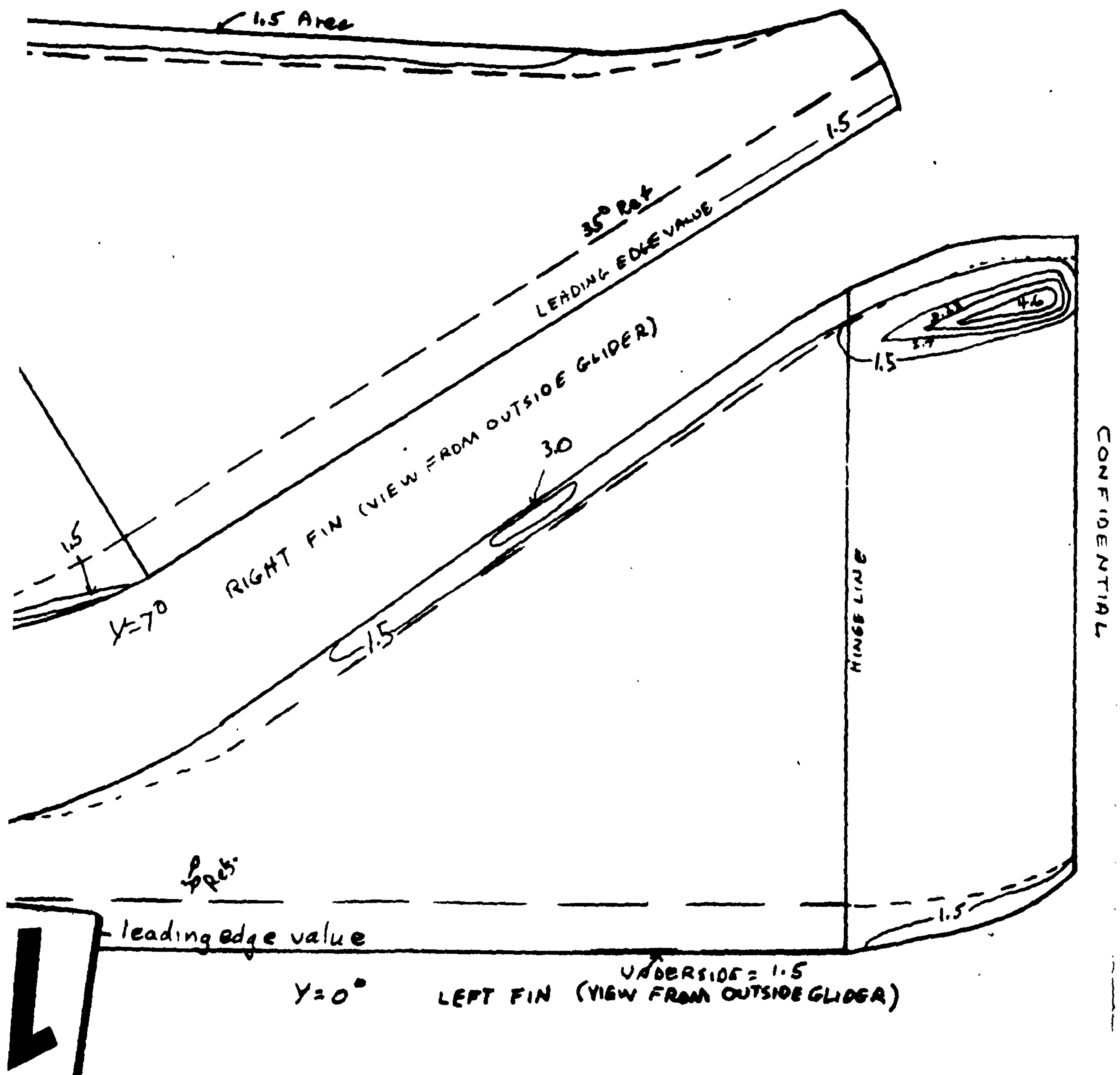
Boeing R-4 12/21/62

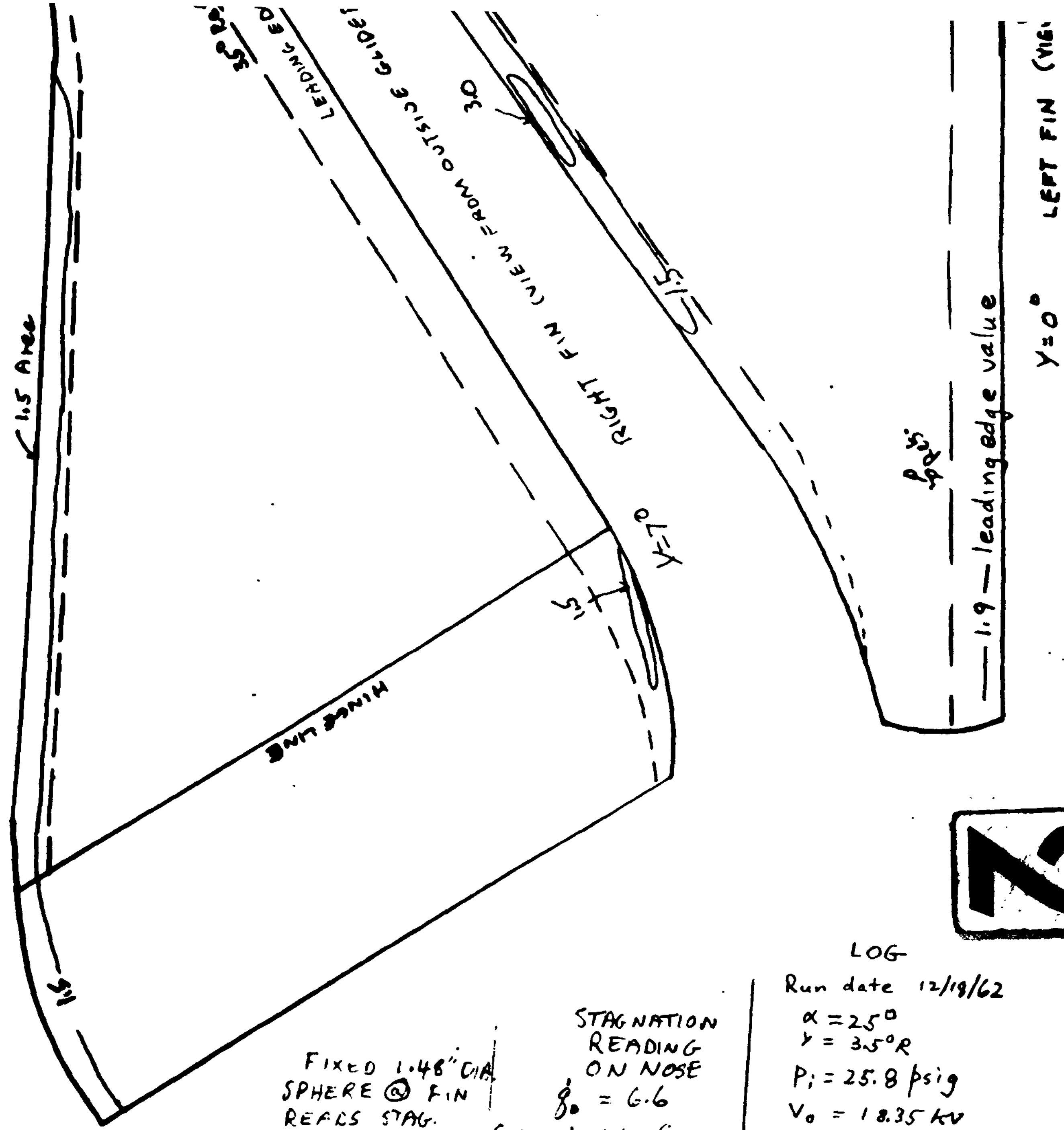
INSTALLATION DRAWING

MODEL PHOTOGRAPH

CONFIDENTIAL

D2-80911
9


1.5 Area
1.5
35° Ref
LEADING EDGE VALUE
RIGHT FIN (VIEW FROM OUTSIDE GLIDER)
Y=70
1.5
3.0
1.5
2.3
4.6
1.5
HINGE LINE
CONFIDENTIAL
leading edge value
1.5
UNDERSIDE = 1.5
Y=0°
LEFT FIN (VIEW FROM OUTSIDE GLIDER)



2

LOG

Run date 12/19/62

$\alpha = 25°$

$\gamma = 3.5°R$

$P_i = 25.8$ psig

$V_o = 18.35$ KV

$P_{back} = 1 \mu Hg$

6" DIAMETER 55° sweep

Left Rudder 10°

Right Rudder 20°

STAGNATION READING ON NOSE

$\dot{q}_o = 6.6$

Corrected to fin Station $\dot{q}_{o_{corr}} = 4.85$

FIXED 1.48" DIA. SPHERE @ FIN READS STAG. RATE OF 3.3

MOVING 1.48" DIA. SPHERE @ FIN READS 3.3 ALSO

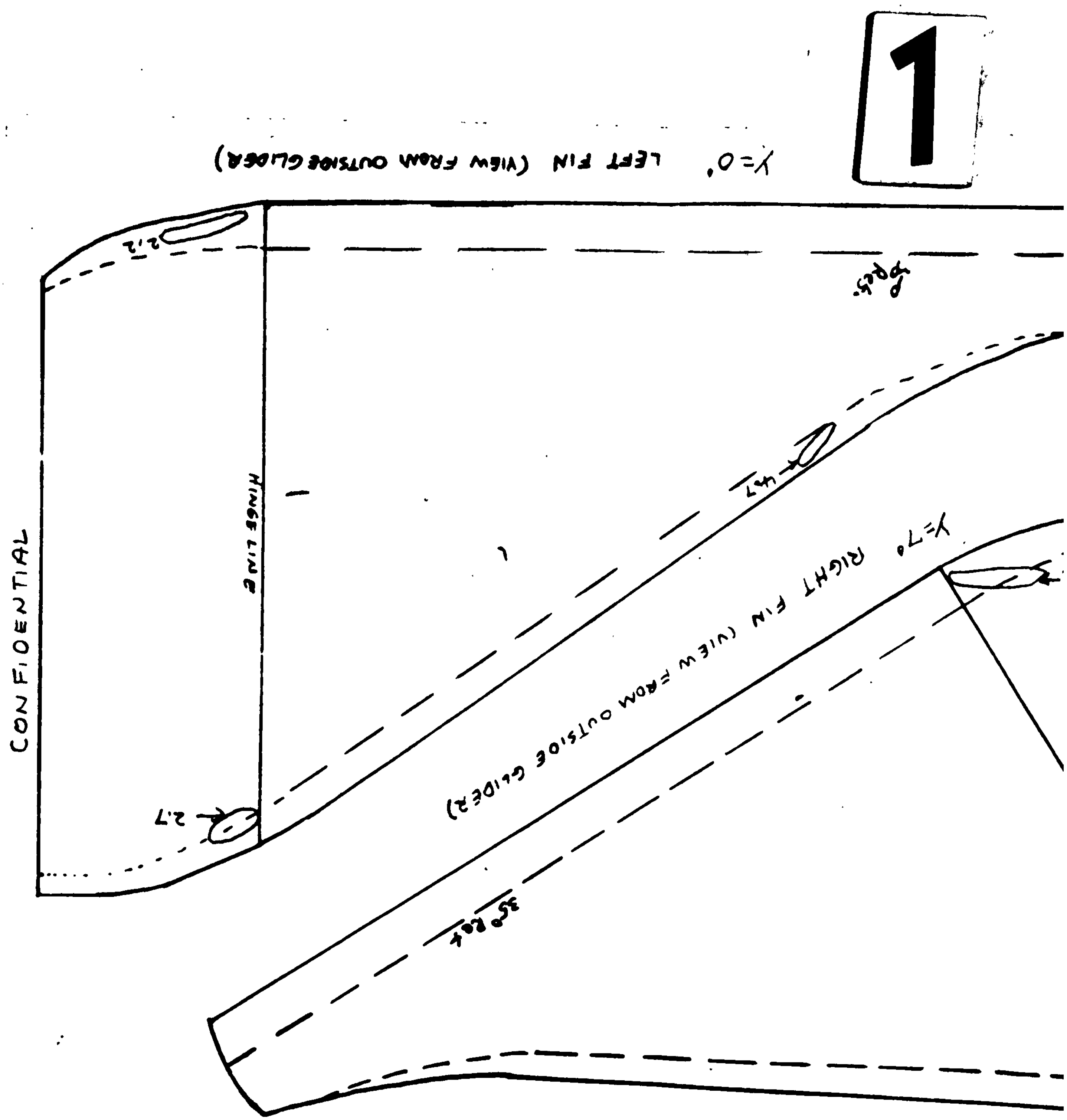
R-1

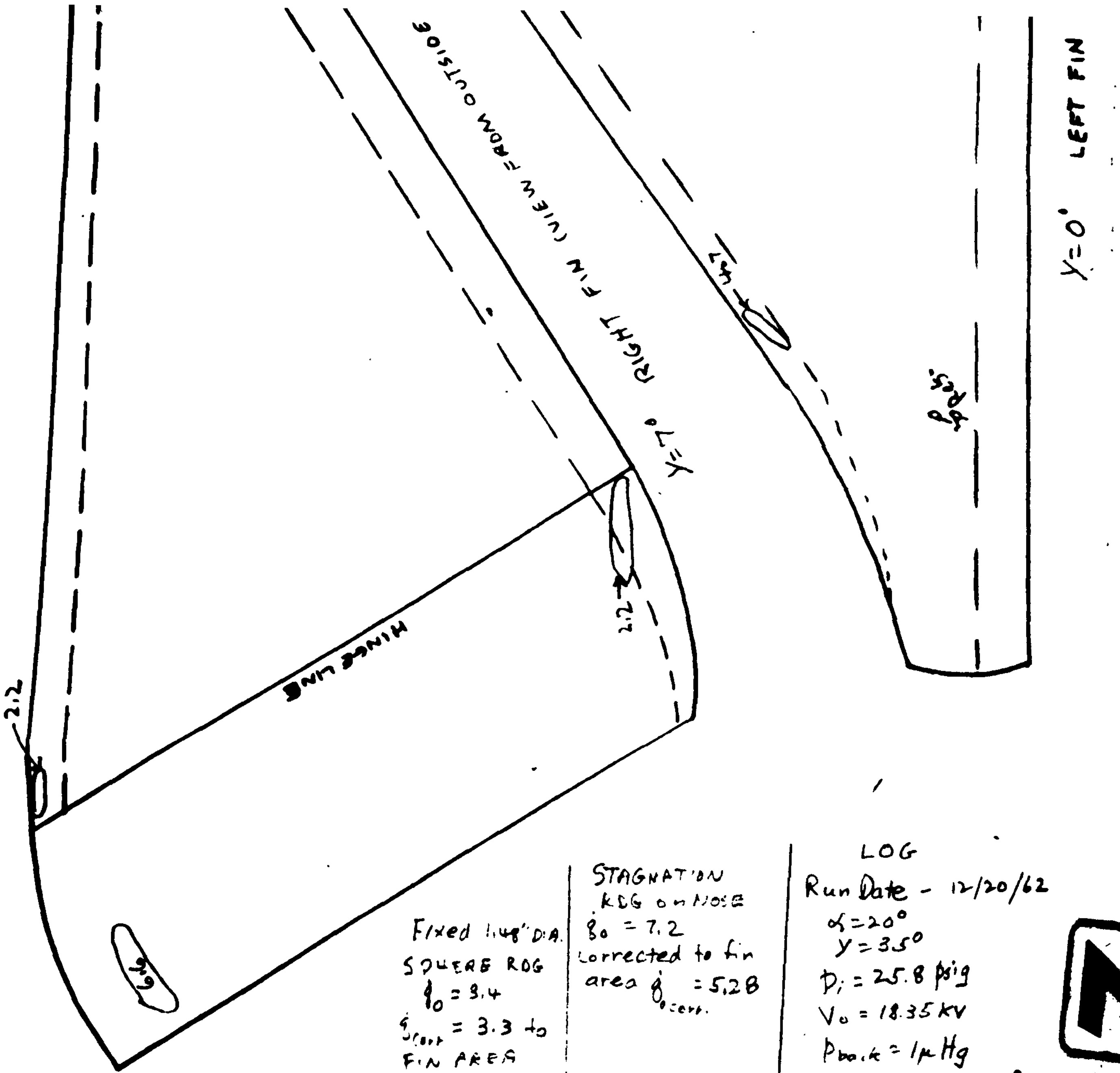
Flight rates: color Δ X 8.8 w/cm²
no vorticity

Tunnel rates: color Δ X 159 w/cm²
no vorticity

CONFIDENTIAL

D2-80911
10


1
Y=0° LEFT FIN (VIEW FROM OUTSIDE GLIDER)
Y=7° RIGHT FIN (VIEW FROM OUTSIDE GLIDER)
HINGE LINE
CONFIDENTIAL
2.2
2.7
4.7



Flight rates = Color # X 8.8 w/cm²
no vorticity
Tunnel rates = Color # x169 w/cm²
no vorticity

Fixed 1.48" DIA.
SPHERE RDG
$\dot{q}_0 = 3.4$
$\dot{q}_{corr} = 3.3$ to
FIN AREA

MOVING 1.48" DIA
SPHERE @ FIN
reads 3.3 also

STAGNATION
RDG on NOSE
$\dot{q}_0 = 7.2$
corrected to fin
area $\dot{q}_{0\,corr.} = 5.28$

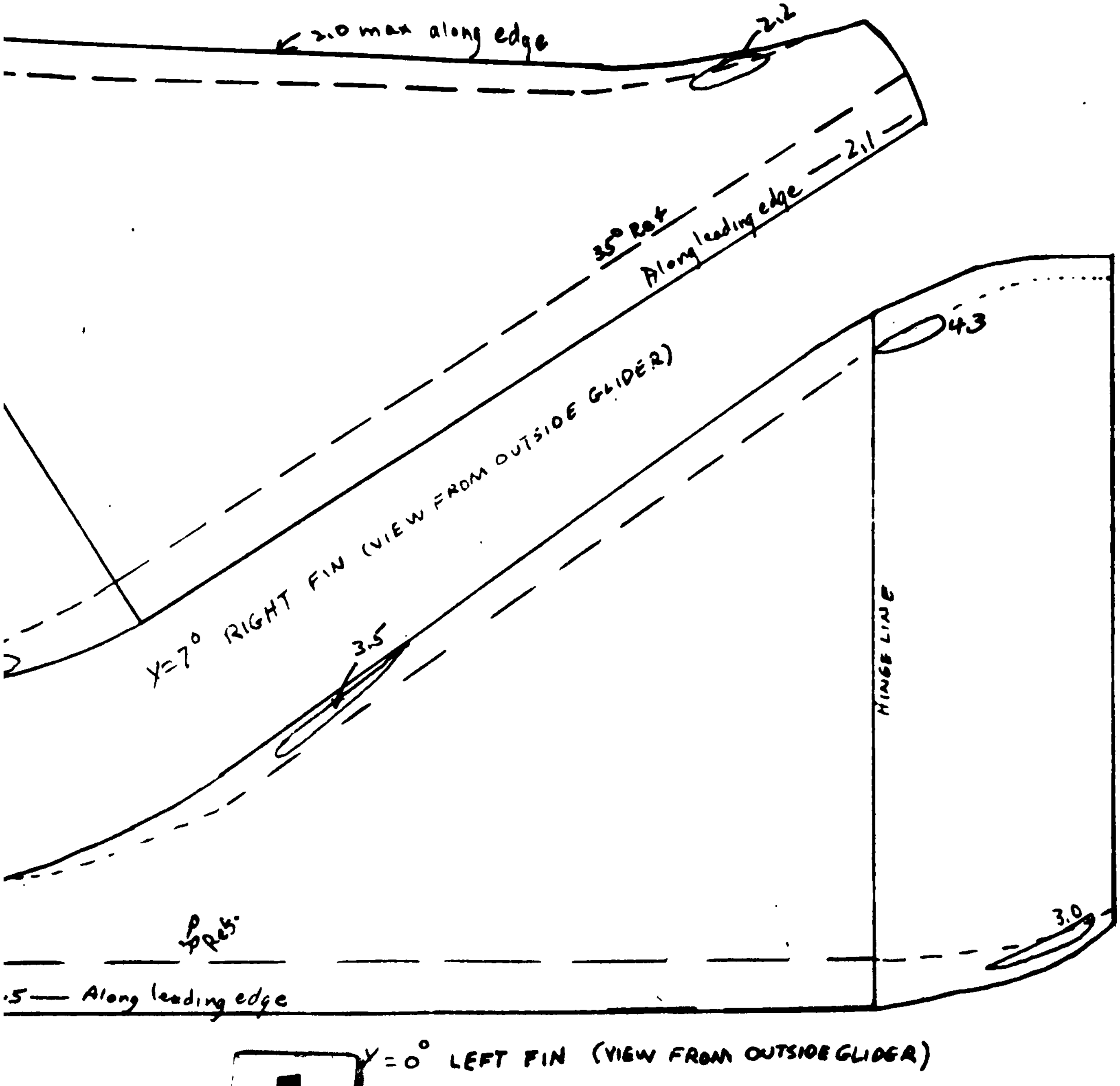
LOG
Run Date - 12/20/62
$\alpha = 20°$
$\gamma = 35°$
$P_i = 25.8$ psig
$V_0 = 18.35$ KV
$P_{back} = 1\mu$ Hg
6" Diameter 55° sweep
left Rudder 10°
Right Rudder 20°

2

R-2

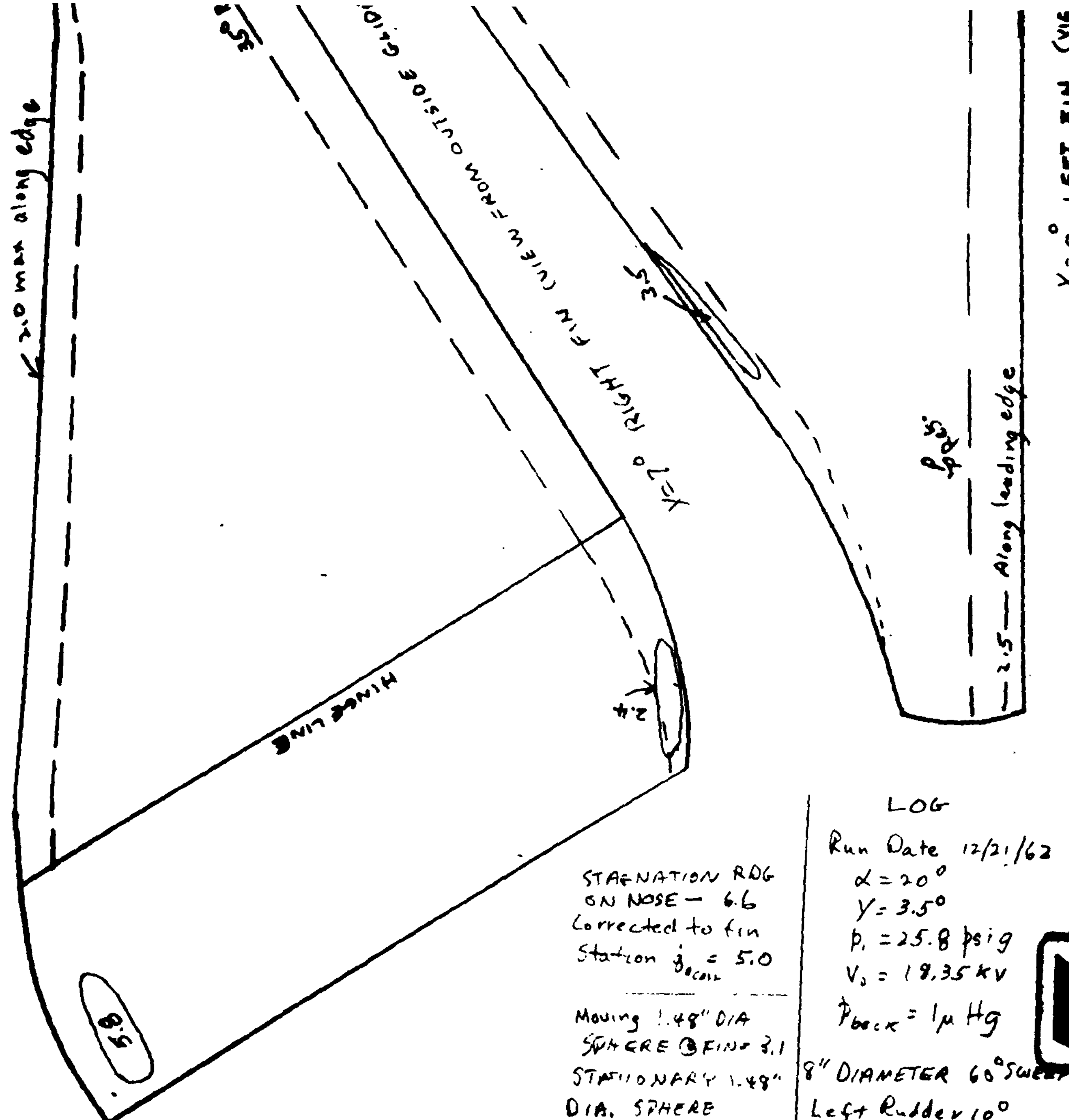
CONFIDENTIAL

D2-80911
11



CONFIDENTIAL

1



Flight rates = color # × 9.37 w/cm² no vorticity
Tunnel rates = color # × 170 w/cm² no vorticity

STAGNATION RDG ON NOSE — 6.6
Corrected to fin Station $\dot{q}_{corr}$ = 5.0

Moving 1.48" DIA SPHERE @ FIN = 3.1
STATIONARY 1.48" DIA. SPHERE Corrected to fin Station = 3.16

1/4" OD ROD NORMAL TO FLOW = 4.6 @ FIN STATION

LOG
Run Date 12/21/62
$\alpha = 20°$
$\gamma = 3.5°$
$p_1 = 25.8$ psig
$V_0 = 18.35$ kV
$p_{back} = 1\mu$ Hg

8" DIAMETER 60° SWEEP
Left Rudder 10°
Right Rudder 20°

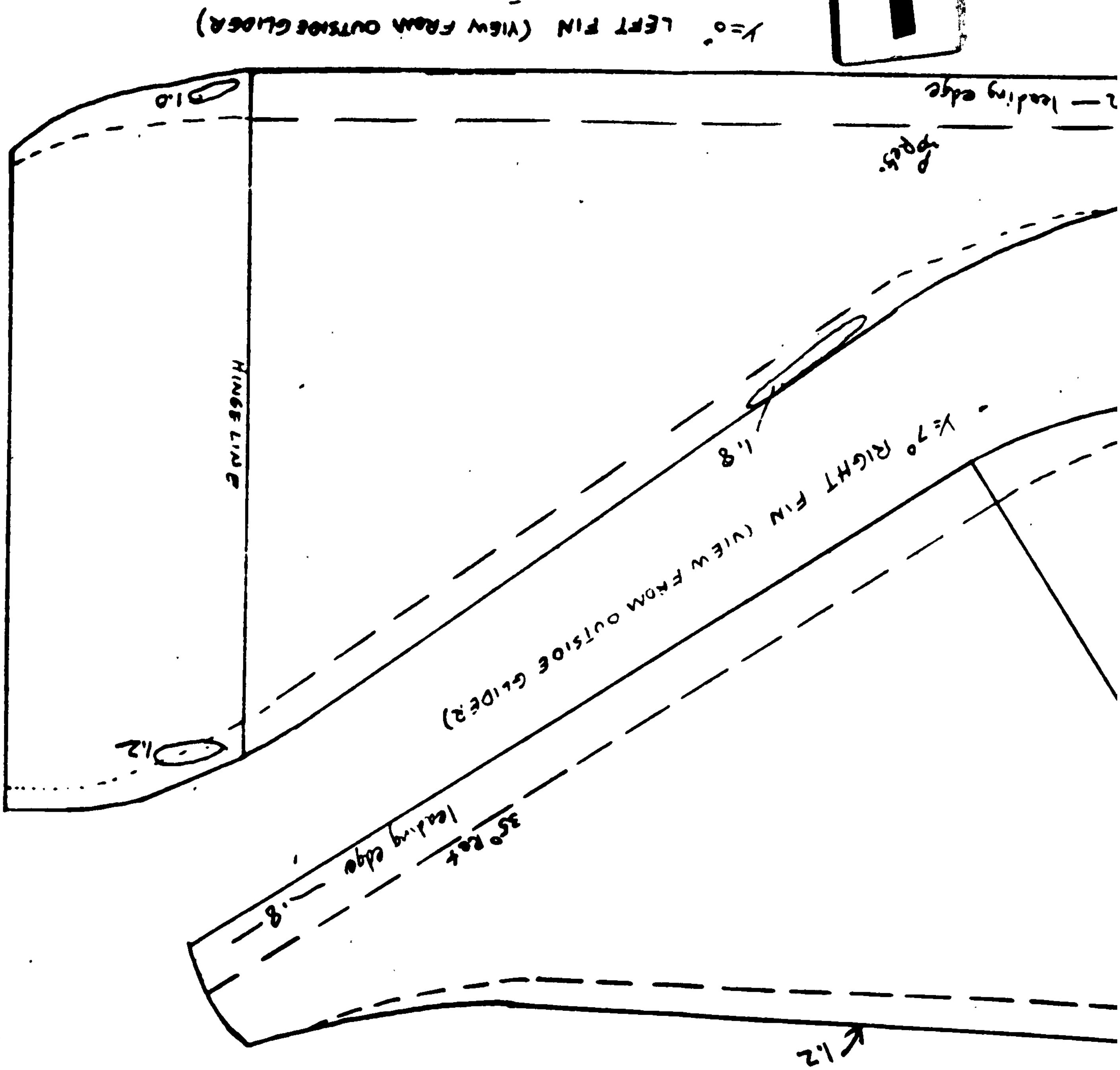
2

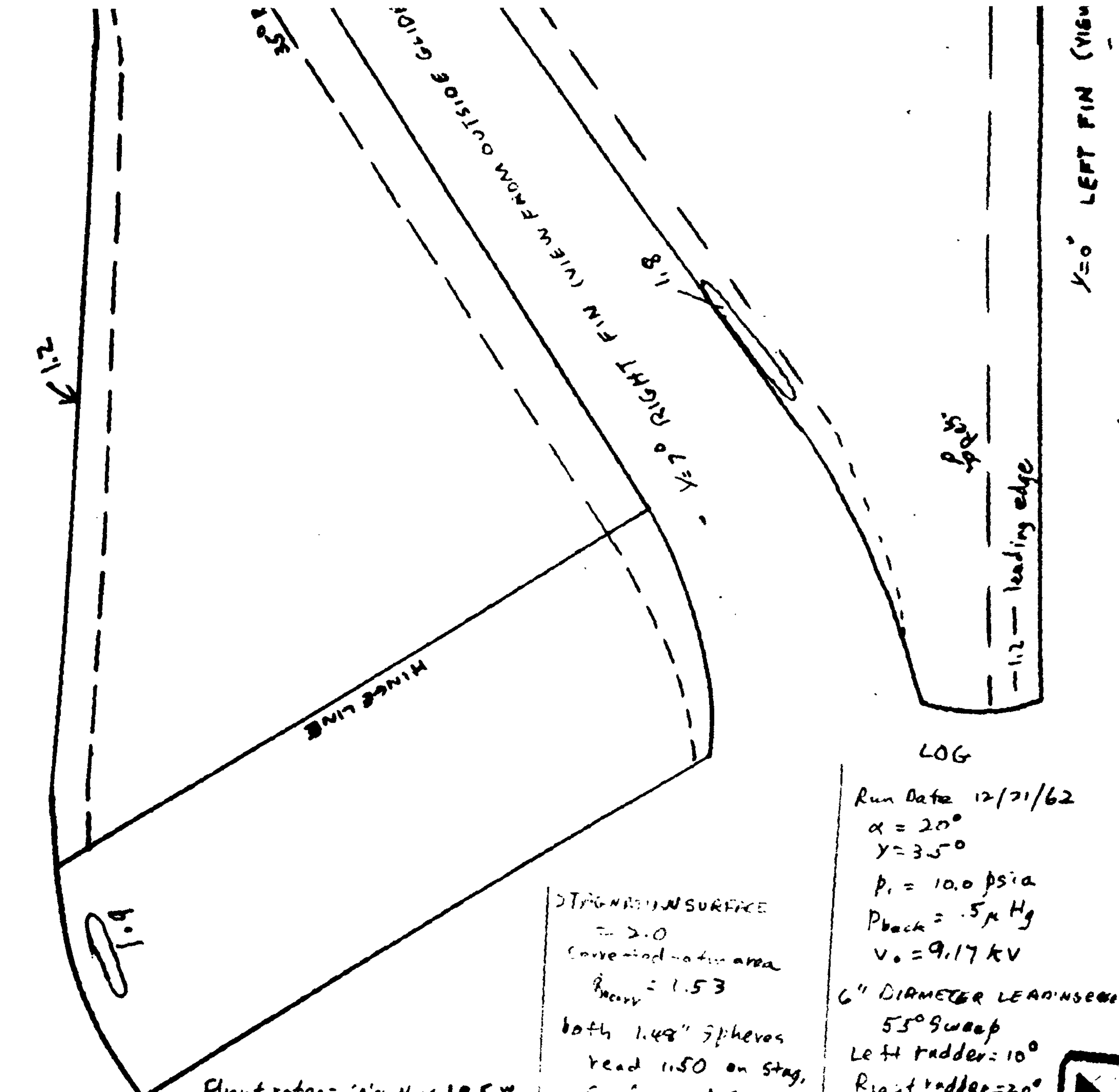
R-3
CONFIDENTIAL

D2-80911
12

1

CONFIDENTIAL





Flight rates = Color # × 19.5 $\frac{w}{cm^2}$
no vorticity

Tunnel rates = Color # × 160 $w/_{cm^2}$

STAGNATION SURFACE
= 2.0
Corrected to fin area
$\dot{q}_{corr}$ = 1.53

both 1.48" spheres
read 1.50 on stag.
Surface at fin station

note: use of 1.48"
spheres gives stag.
line rate of 2.35
at fin station

LOG

Run Date 12/21/62
$\alpha = 20°$
$\psi = 3.5°$
$p_1 = 10.0$ psia
$p_{back} = .5\mu$ Hg
$V_0 = 9.17$ kV

6" DIAMETER LEADING EDGE
55° Sweep
Left rudder = 10°
Right rudder = 20°

2

R-4
CONFIDENTIAL

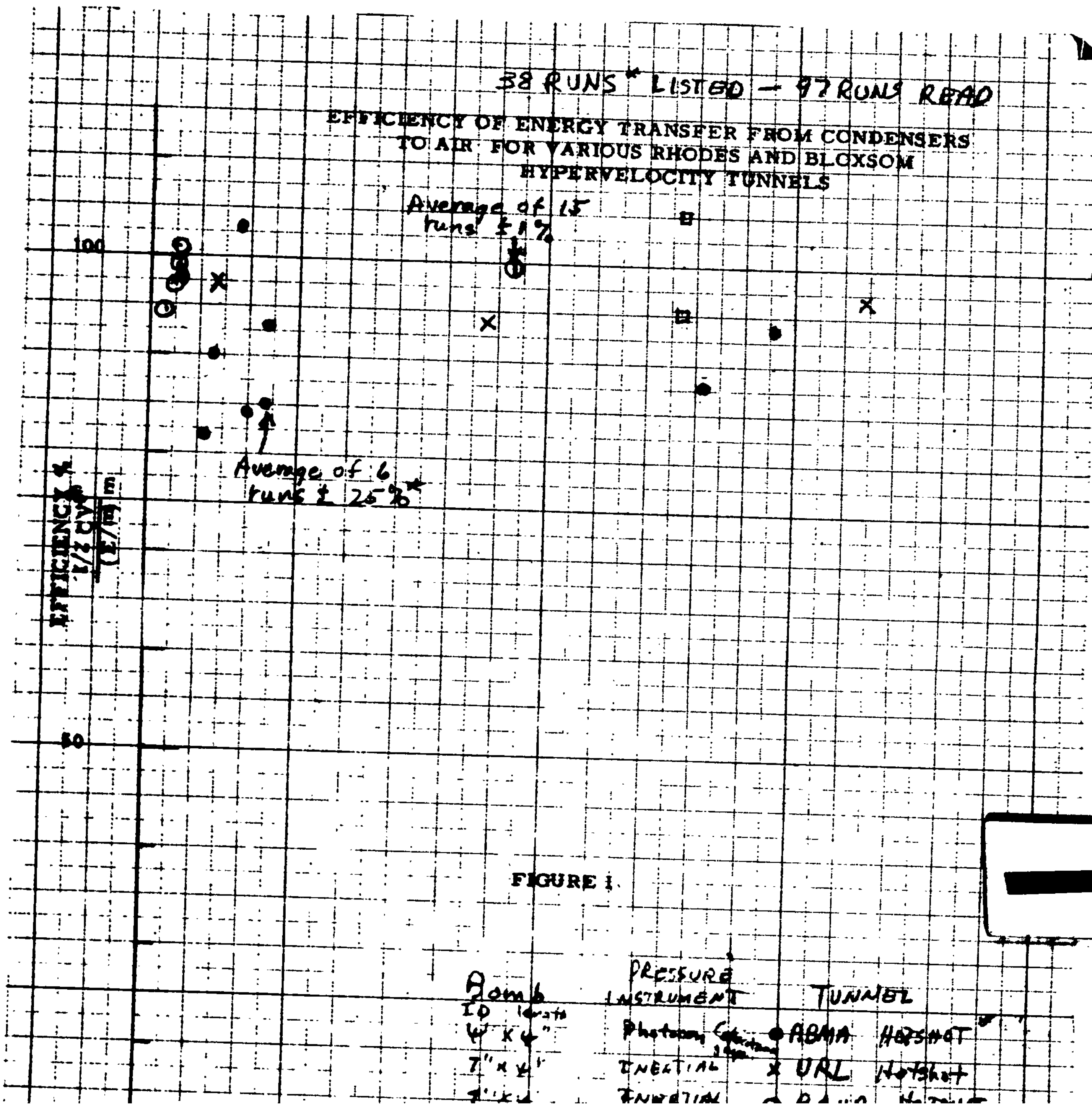
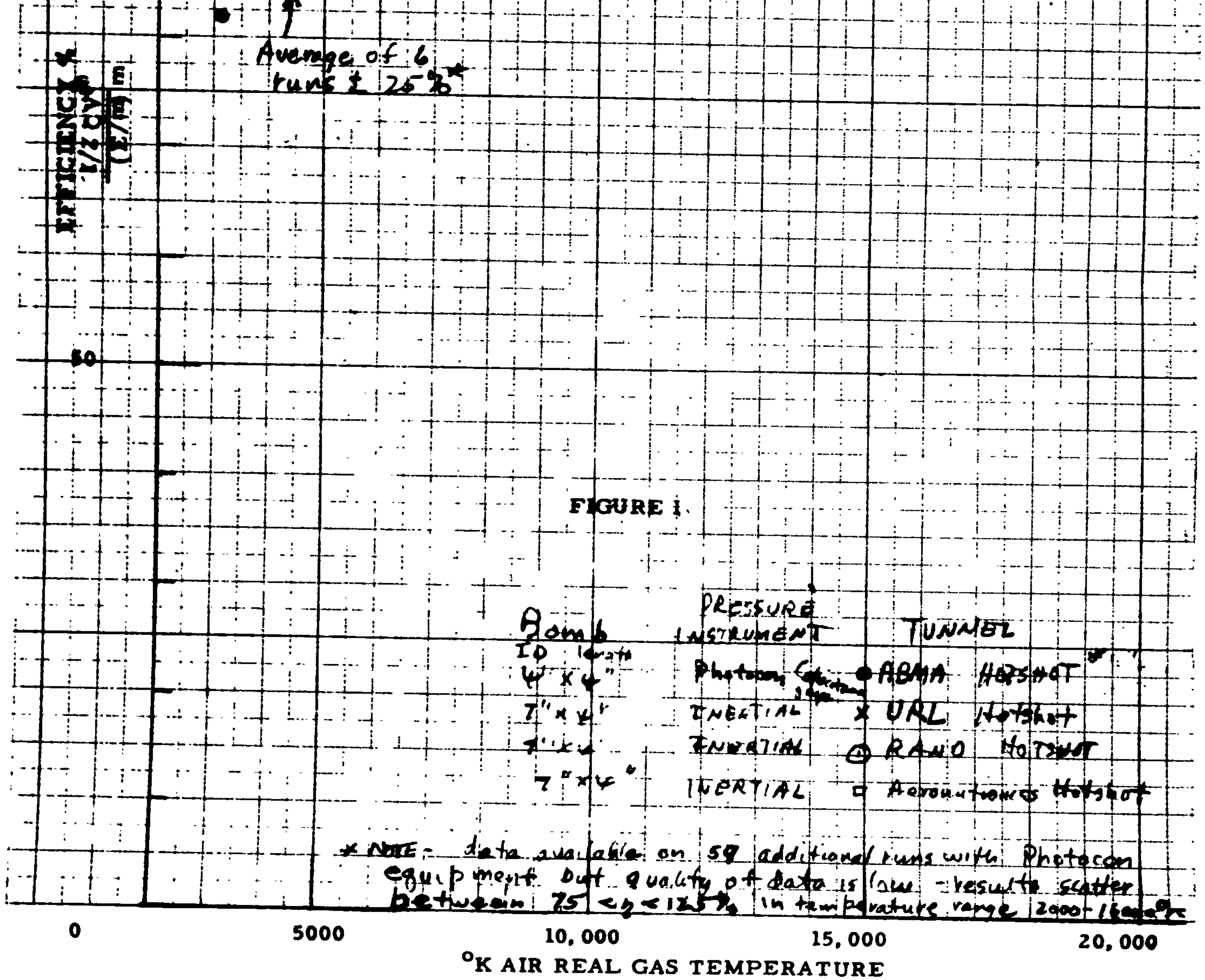

38 RUNS* LISTED — 97 RUNS READ
EFFICIENCY OF ENERGY TRANSFER FROM CONDENSERS TO AIR FOR VARIOUS RHODES AND BLOXSOM HYPERVELOCITY TUNNELS
Average of 15 runs ± 1%
Average of 6 runs ± 25%*
100
50
EFFICIENCY %
1/2 CV²
(E/m) m
Bomb
ID length
PRESSURE INSTRUMENT
TUNNEL
Photocon Calibrating gage
ABMA Hotshot*
INERTIAL
URL Hotshot

FIGURE 1



EFFICIENCY % 1/2 CV 2/1 (E/M) E
50
Average of 6 runs ± 25%*
Bomb
ID length
4" x 4"
7" x 4"
4" x 4
7" x 4"
PRESSURE INSTRUMENT
Photocon
INERTIAL
INERTIAL
INERTIAL
TUNNEL
ABMA HOTSHOT
URL Hotshot
RAND HOTSHOT
Aeronutronics Hotshot
* NOTE - data available on 58 additional runs with Photocon equipment but quality of data is low - results scatter between 75 < η < 125% in temperature range 2000-16000°K
0
5000
10,000
15,000
20,000
°K AIR REAL GAS TEMPERATURE

FIGURE 1

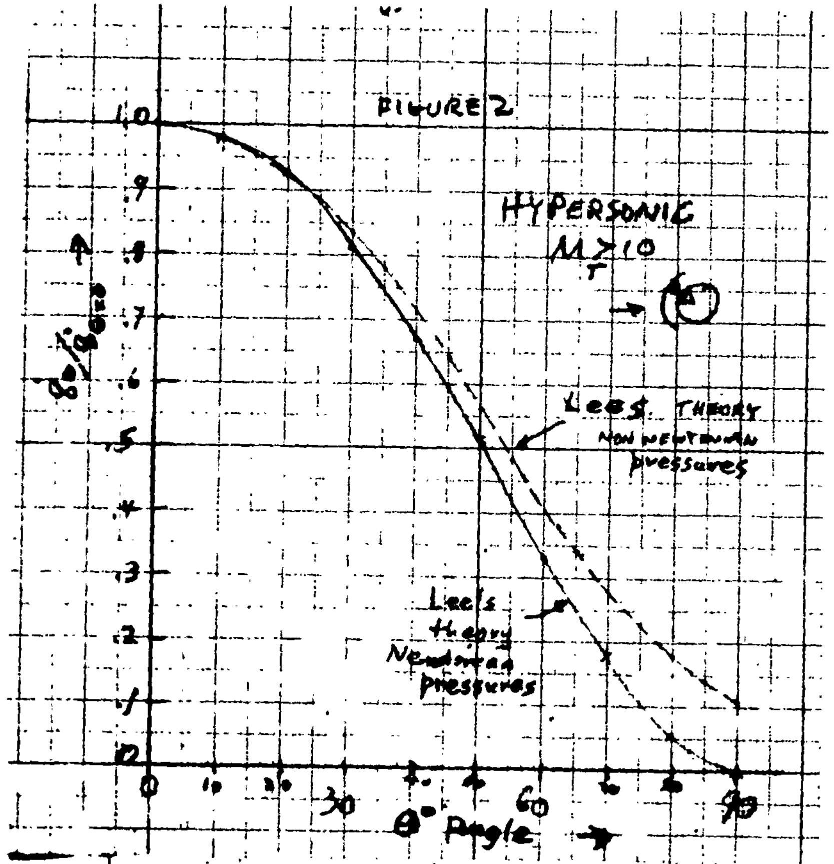
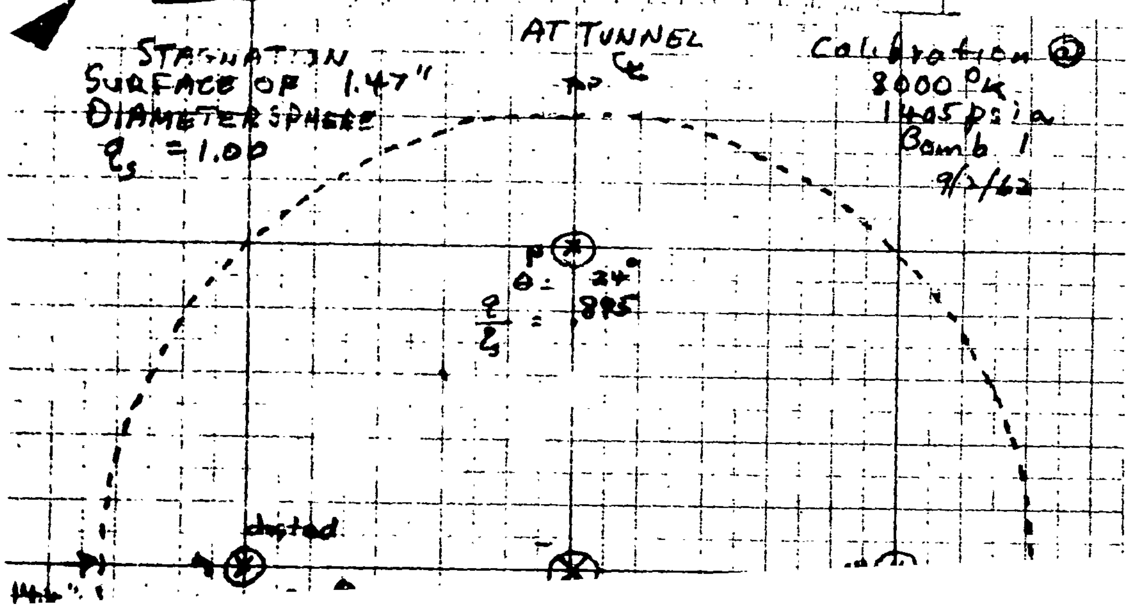
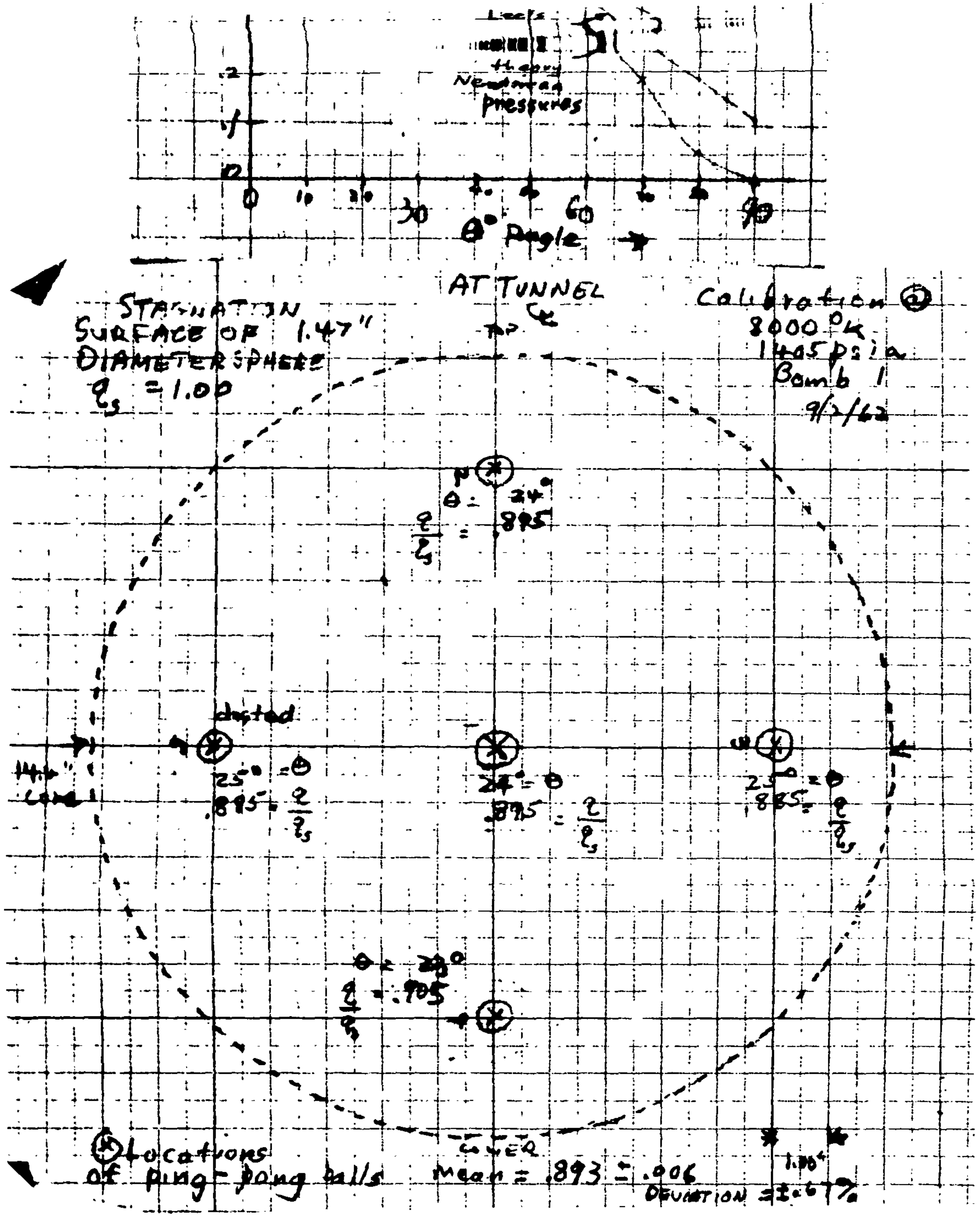


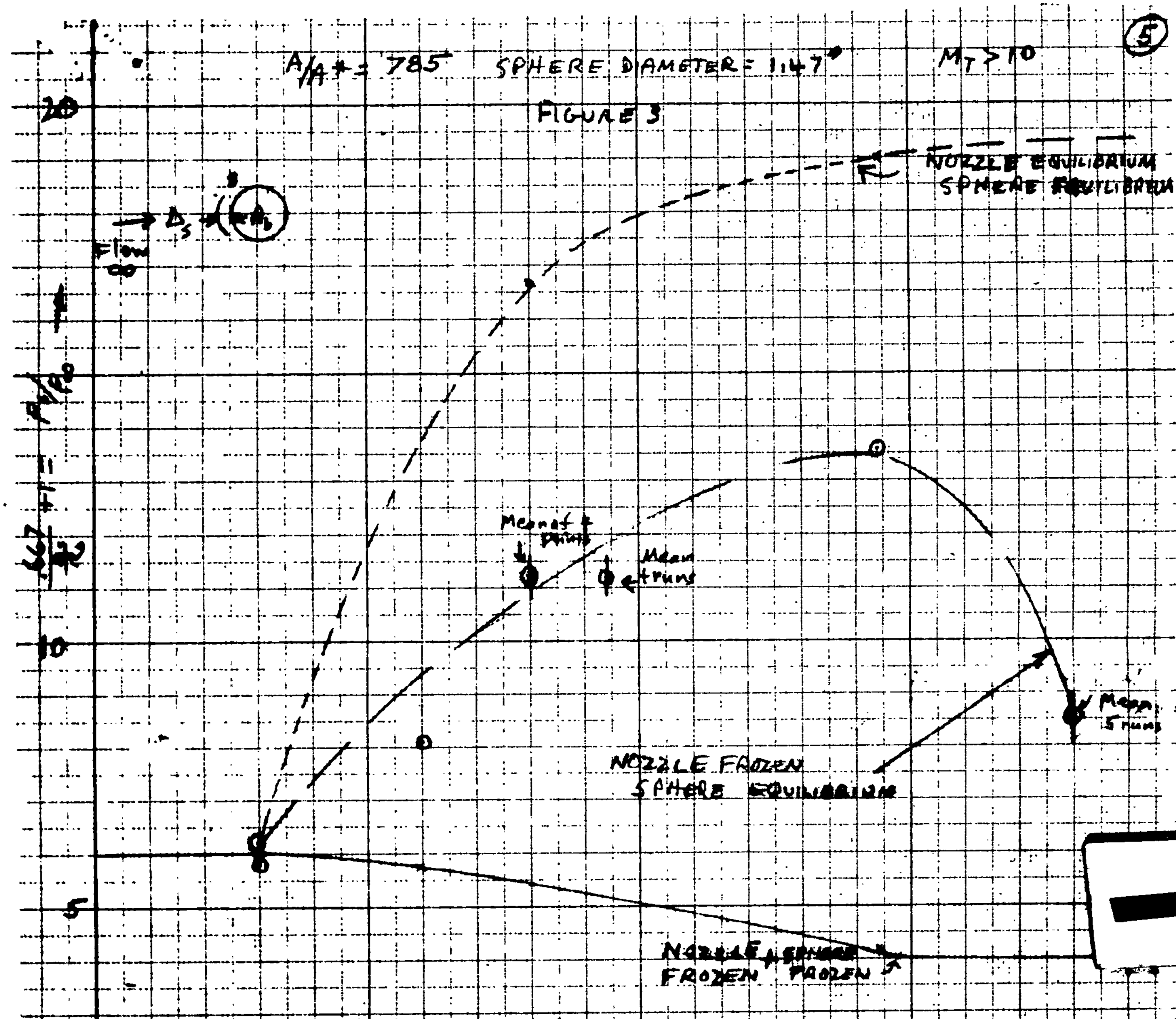
FIGURE 2
HYPERSONIC
M > 10
Lees THEORY
NON NEWTONIAN
pressures
Lee's
theory
Newtonian
pressures
q/q_s
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
10
20
30
40
50
60
70
80
90
θ° Angle


AT TUNNEL ℄
STAGNATION
SURFACE OF 1.47"
DIAMETER SPHERE
q_s = 1.00
Calibration ②
8000 °K
1405 psia
Bomb 1
9/2/62
θ = 24°
q/q_s = .895
dusted

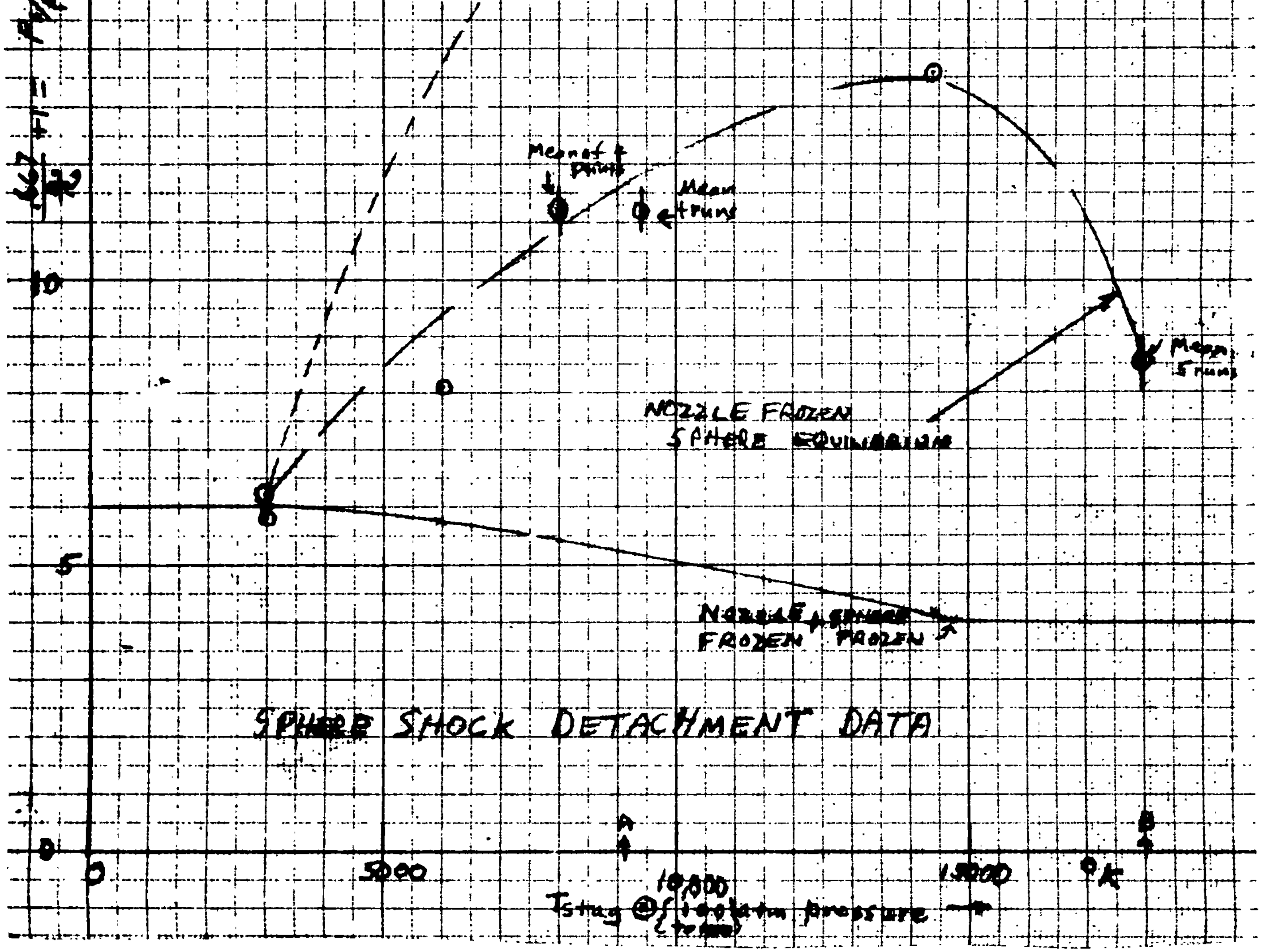

Theory
Newtonian
Pressures
0
10
20
30
40
50
60
70
80
90
θ° Angle
.1
.2
STAGNATION
SURFACE OF 1.47"
DIAMETER SPHERE
q_s = 1.00
AT TUNNEL ℄
TOP
Calibration ②
8000 °K
1405 psia
Bomb 1
9/3/62
θ = 24°
$\frac{q}{q_s}$ = .895
dusted
25° = θ
.895 = $\frac{q}{q_s}$
24° = θ
.895 = $\frac{q}{q_s}$
25° = θ
.885 = $\frac{q}{q_s}$
θ = 29°
$\frac{q}{q_s}$ = .905
1.44"
Cone
COVER
Locations of ping-pong balls
Mean = .893 ± .006
Deviation = ±0.67%
1.90"

2

D2 80911
15



SPHERE SHOCK DETACHMENT DATA



Mean of 4 points
Mean 4 runs
Mean 5 runs
NOZZLE FROZEN SPHERE EQUILIBRIUM
NOZZLE & SPHERE FROZEN FROZEN
SPHERE SHOCK DETACHMENT DATA
0
5
10
5000
10,000
15000
°K
A
B
T_{stag} @ 100 atm pressure

D2-80911
16

Rhodes and Bloxsom APPLIED PHYSICS RESEARCH

7343 DEERING AVENUE
CANOGA PARK, CALIFORNIA
DIAMOND 0-2707

FIGURE 4 SERIES

January 4, 1963

CALIBRATION SUMMARY: 20.5" NOZZLE, 72" STATION .750" THROAT

I) ISENTROPIC CORE: 3 RUNS (HEAT TRANSFER)
1 RUN (DYNAMIC PRESSURE)

II) LONGITUDINAL CALIBRATION: 2 RUNS (HEAT TRANSFER)
1 RUN (DYNAMIC PRESSURE)

III) FLOW ANGULARITY: 2 RUNS

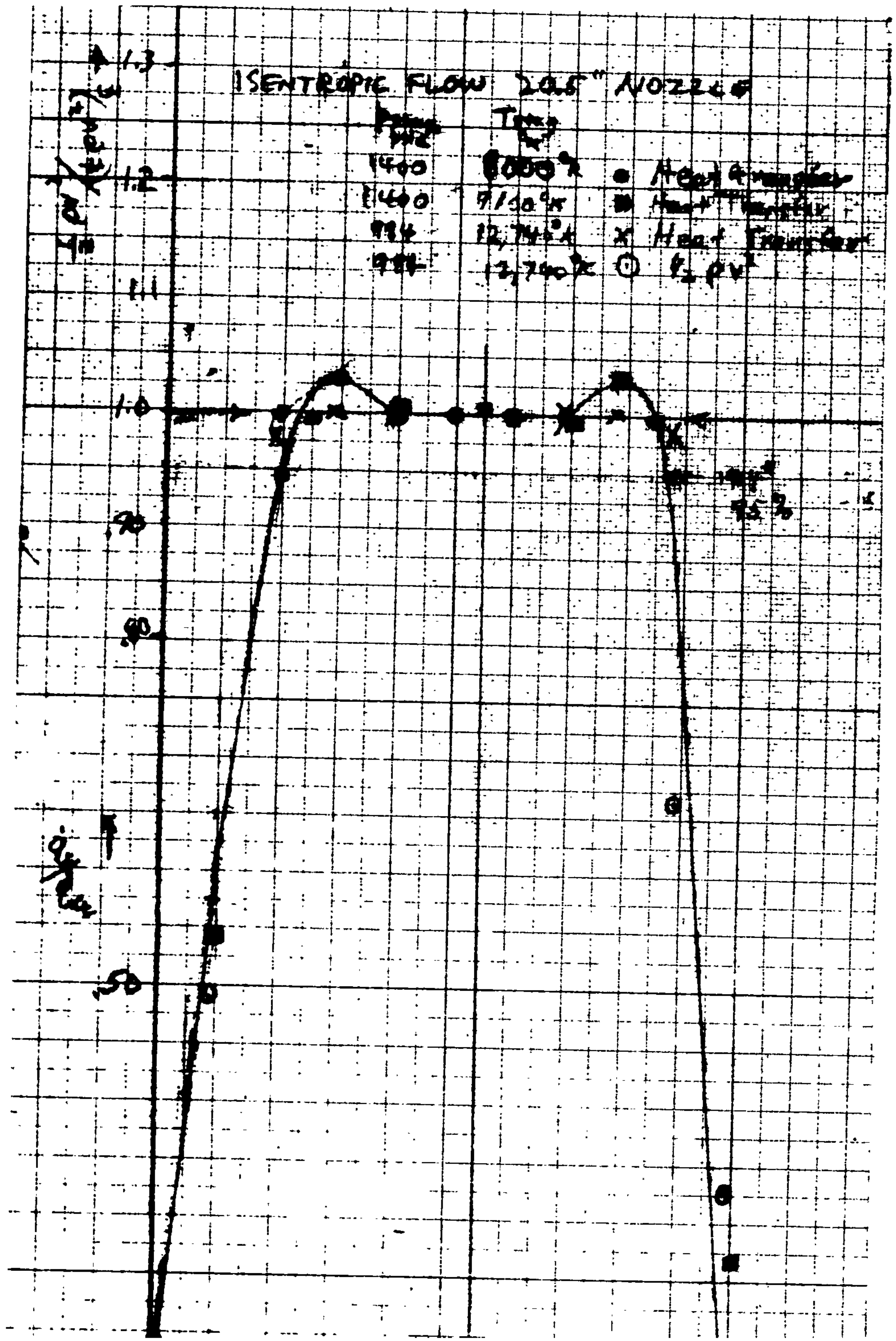
1

CALIBRATION SUMMARY: 20.5" NOZZLE, 72" STATION .750" THROAT

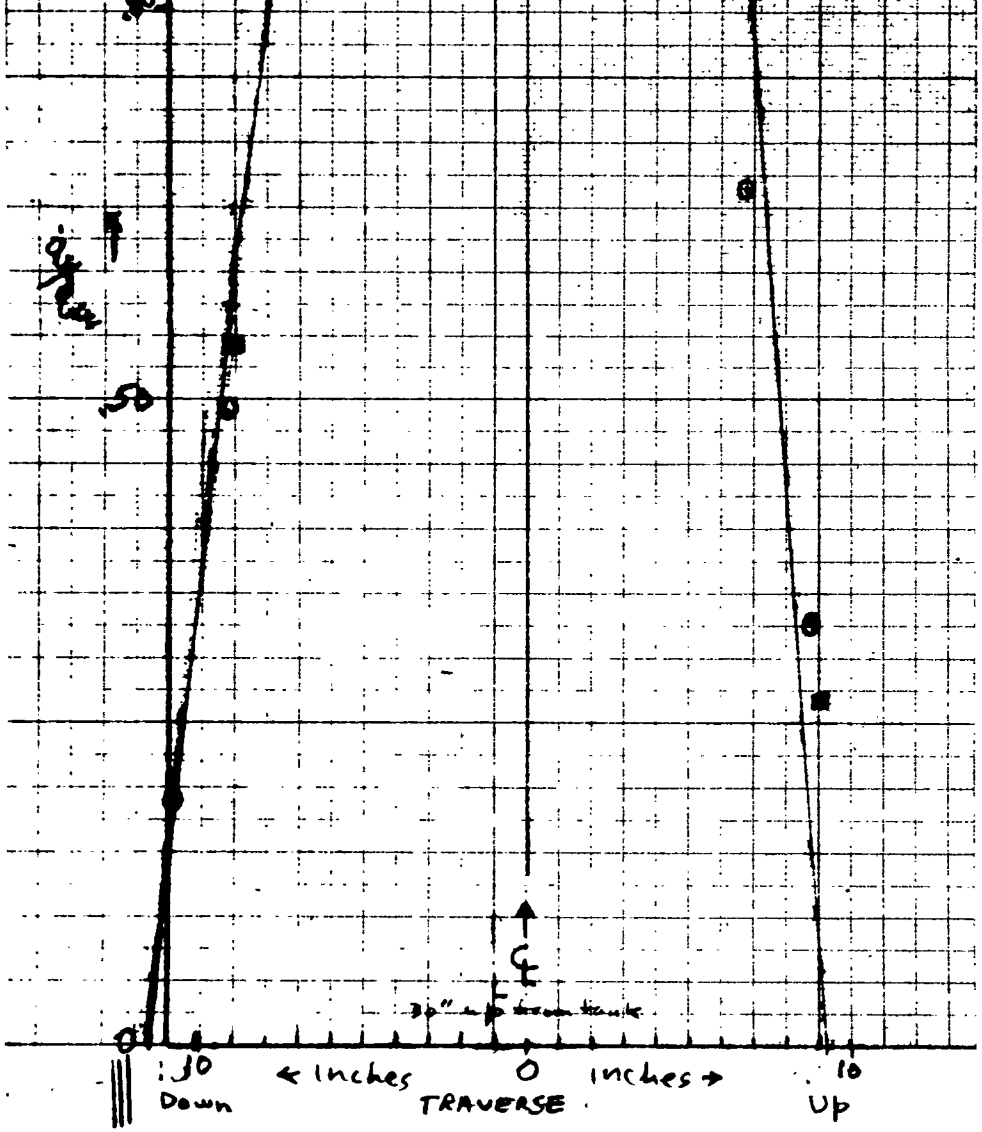
I) ISENTROPIC CORE: 3 RUNS (HEAT TRANSFER)
1 RUN (DYNAMIC PRESSURE)

II) LONGITUDINAL CALIBRATION: 2 RUNS (HEAT TRANSFER)
1 RUN (DYNAMIC PRESSURE)

III) FLOW ANGULARITY: 2 RUNS

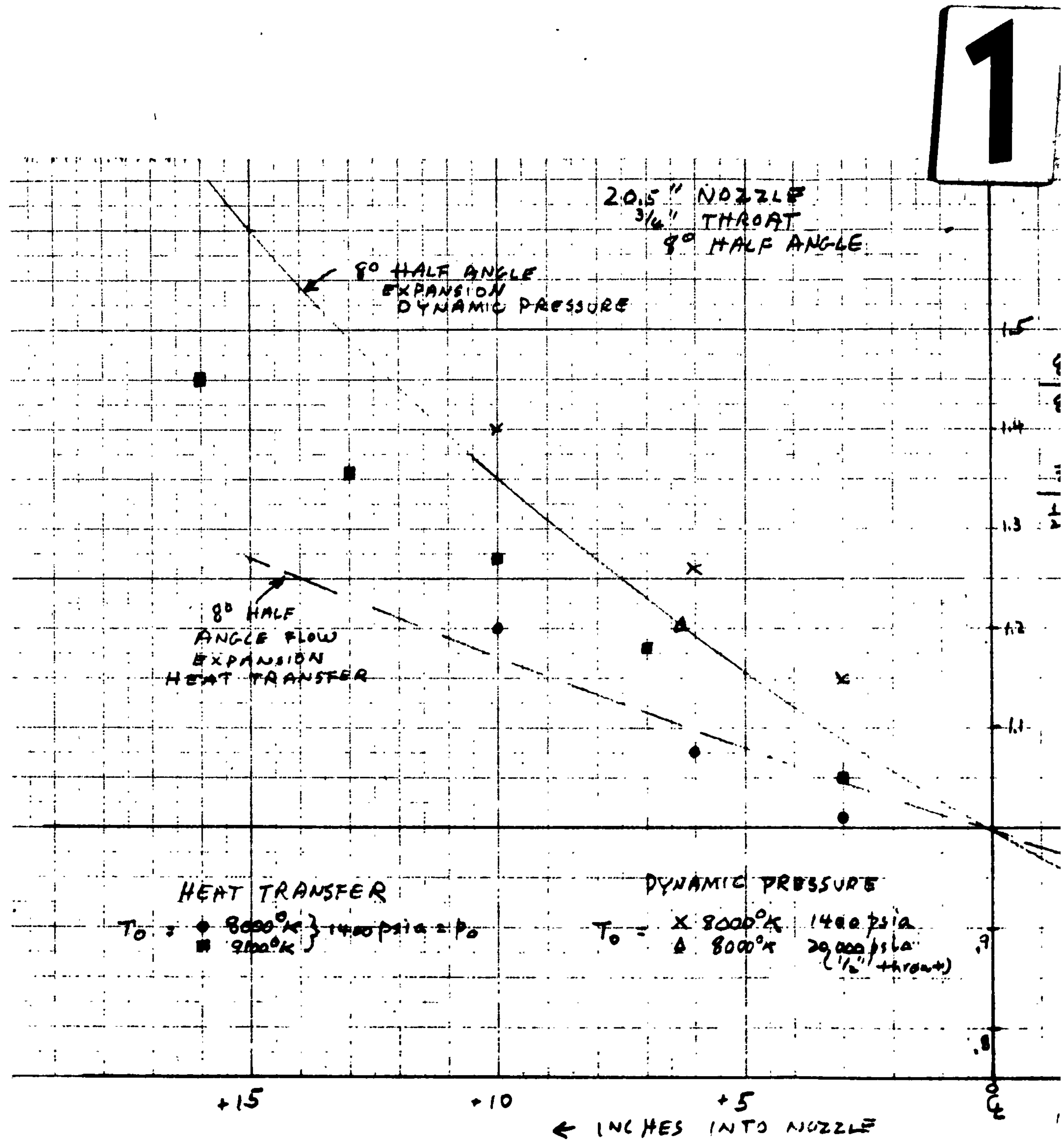

ISENTROPIC FLOW 20.5" NOZZLE
Temp
1400 6000°K ● Heat Transfer
1400 9130°K ■ Heat Transfer
994 12,740°K x Heat Transfer
994 12,740°K ⊙ ½ ρV²
1.3
1.2
1.1
1.0
.90
.80
.50
95%

1

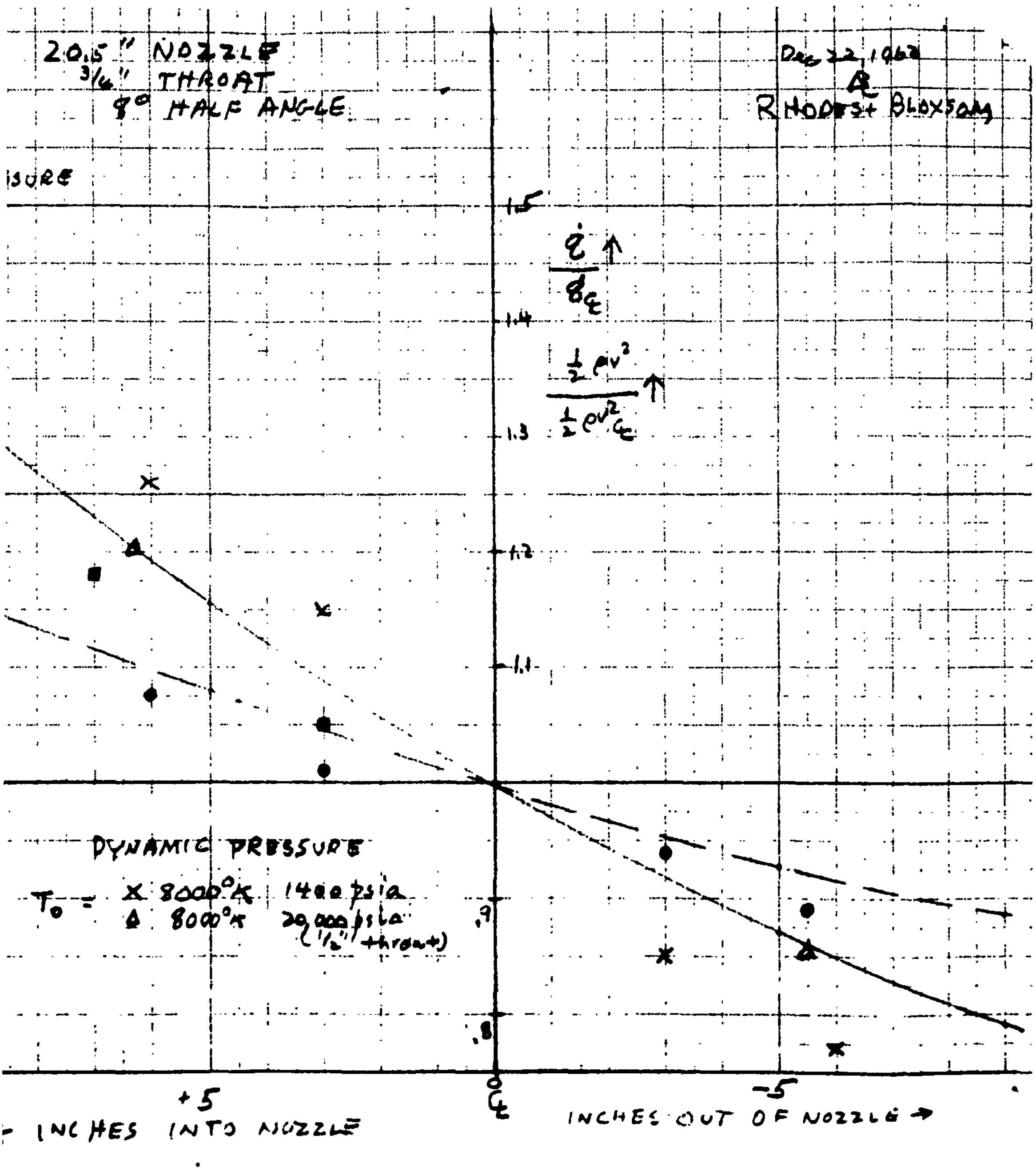


2

D2.80911
18



1
20.5" NOZZLE
3/4" THROAT
8° HALF ANGLE
8° HALF ANGLE EXPANSION DYNAMIC PRESSURE
8° HALF ANGLE FLOW EXPANSION HEAT TRANSFER
HEAT TRANSFER
T0 = ● 8000°K } 1400 psia = p0
■ 9100°K
DYNAMIC PRESSURE
T0 = × 8000°K 1400 psia
△ 8000°K 20,000 psia (1/2" throat)
1.5
1.4
1.3
1.2
1.1
.9
.8
+15
+10
+5
℄
← INCHES INTO NOZZLE

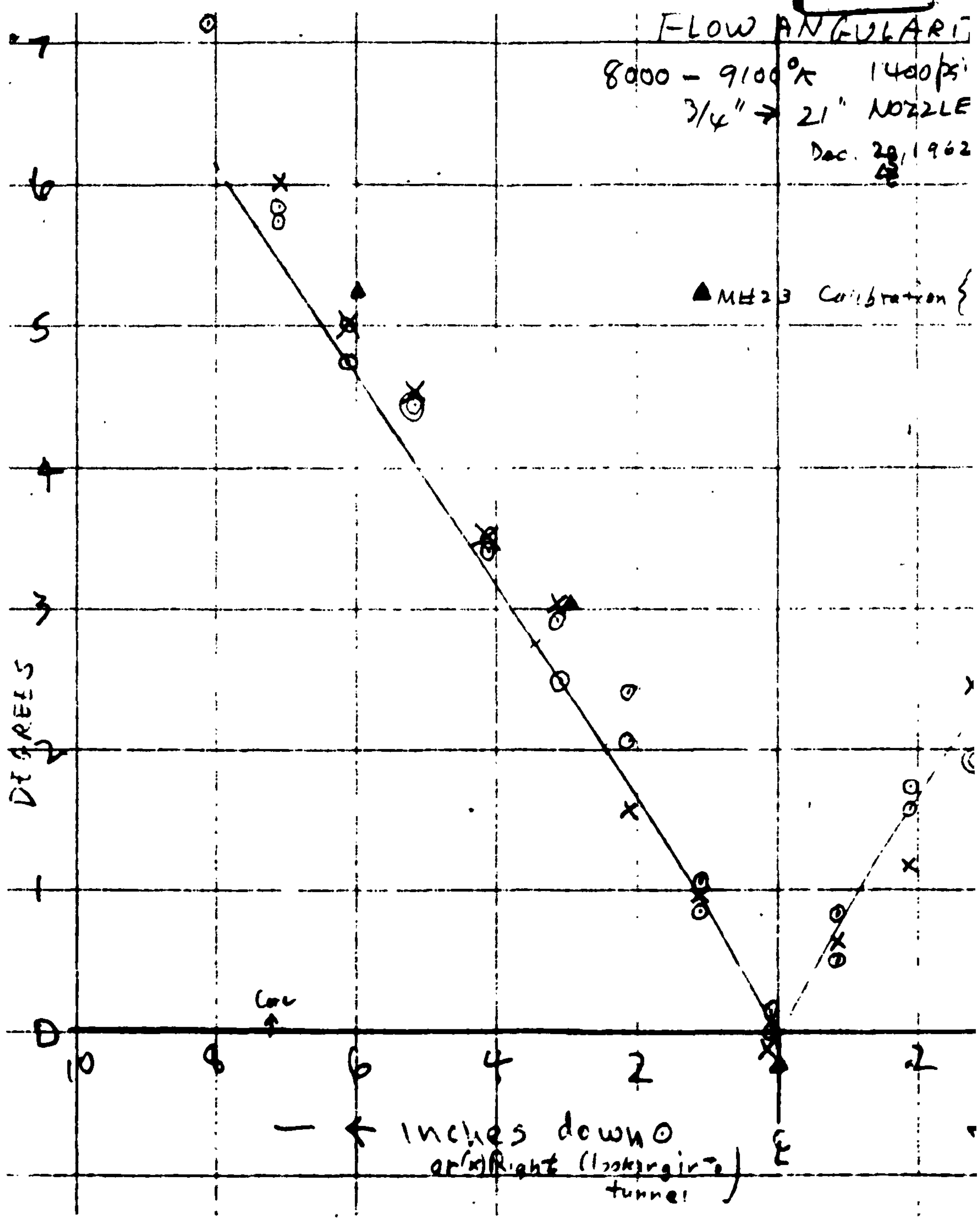


20.5" NOZZLE
3/4" THROAT
8° HALF ANGLE
Dec 22 1962
R
RHODES + BLOXSOM
ISURE
1.5
1.4
1.3
1.2
1.1
.9
.8
DYNAMIC PRESSURE
T_o = X 8000°K 1400 psia
Δ 8000°K 20,000 psia (1/2" throat)
+5
-5
℄
INCHES INTO NOZZLE
INCHES OUT OF NOZZLE →

2

D2-80911
19

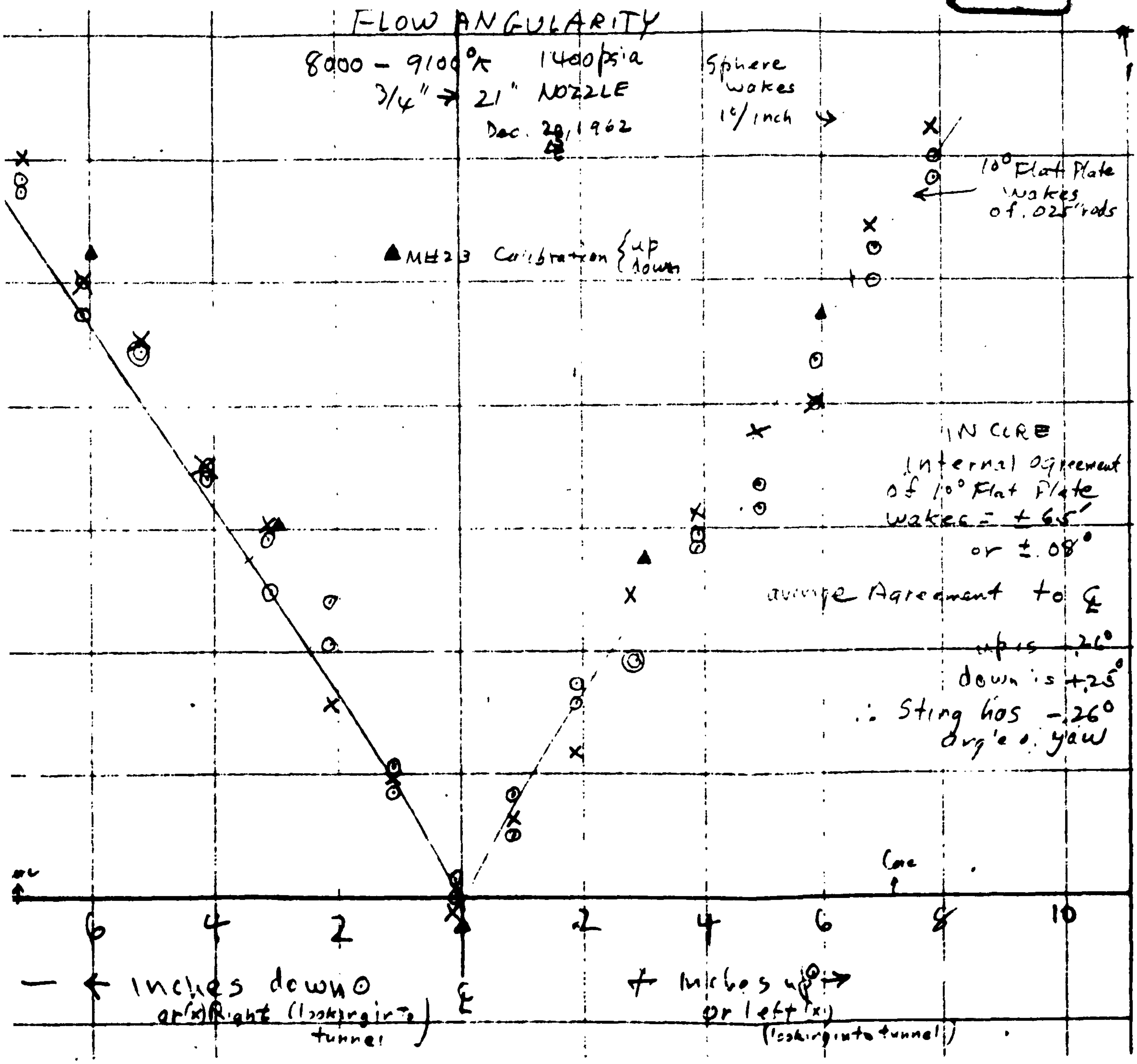
1



FLOW ANGULARI
8000 - 9100°K 1400 psi
3/4" → 21" NOZZLE
Dec. 20, 1962
▲ MH23 Calibration
DEGREES
inches down or (x) Right (looking in tunnel)

2

D2-80911
30


FLOW ANGULARITY
8000 - 9100°K 1400 psia
3/4" → 21" NOZZLE
Dec. 20, 1962
Sphere wakes
1°/inch
10° Flat Plate wakes of .025" rods
▲ MH23 Calibration {up down
IN CORE
Internal agreement of 10° Flat Plate wakes = ± 6.5' or ± .08°
average Agreement to ℄
up is +.26°
down is +.25°
∴ Sting has -.26° deg's of yaw
Core
6
4
2
℄
2
4
6
8
10
− ← inches down ⊙
or (x) Right (looking into tunnel)
+ inches up ⊙ →
or left (x) (looking into tunnel)

Rhodes and Bloxsom APPLIED PHYSICS RESEARCH

7343 DEERING AVENUE
CANOGA PARK, CALIFORNIA
DIAMOND 0-2707

CALIBRATION B Figure 5

January 4, 1962

CALIBRATION REPORT

20.5 INCH NOZZLE, 72 INCH STATION, .750 INCH THROAT

I) ISENTROPIC CORE: 1 RUN (HEAT TRANSFER) UP AND DOWN CENTERLINE and 5.5 INCHES TO RIGHT AND LEFT AT 72 INCH STATION

II) LONGITUDINAL CALIBRATION:
III) FLOW ANGULARITY: (not measured, probably same as 1400 psi calibrations)

Reynolds number/ft 31,000

Ambient density 2.35 $\times 10^{-7}$ gm/cm^3 (measured from sphere acceleration dynamic pressure)

H 2×10^{8} ft^2/sec^2

stagnation pressure 350 psia

stagnation temperature 7500°K

1

January 4, 1962

CALIBRATION REPORT

20.5 INCH NOZZLE, 72 INCH STATION, .750 INCH THROAT

I) ISENTROPIC CORE: 1 RUN (HEAT TRANSFER) UP AND DOWN CENTERLINE and 5.5 INCHES TO RIGHT AND LEFT AT 72 INCH STATION

II) LONGITUDINAL CALIBRATION:
III) FLOW ANGULARITY:
(not measured, probably same as 1400 psi calibrations)

Reynolds number/ft 31,000

Ambient density 2.55 $\times 10^{-7}$ gm/cm^3 (measured from sphere acceleration dynamic pressure)

H 2×10^8 ft^2/sec^2

stagnation pressure 350 psia

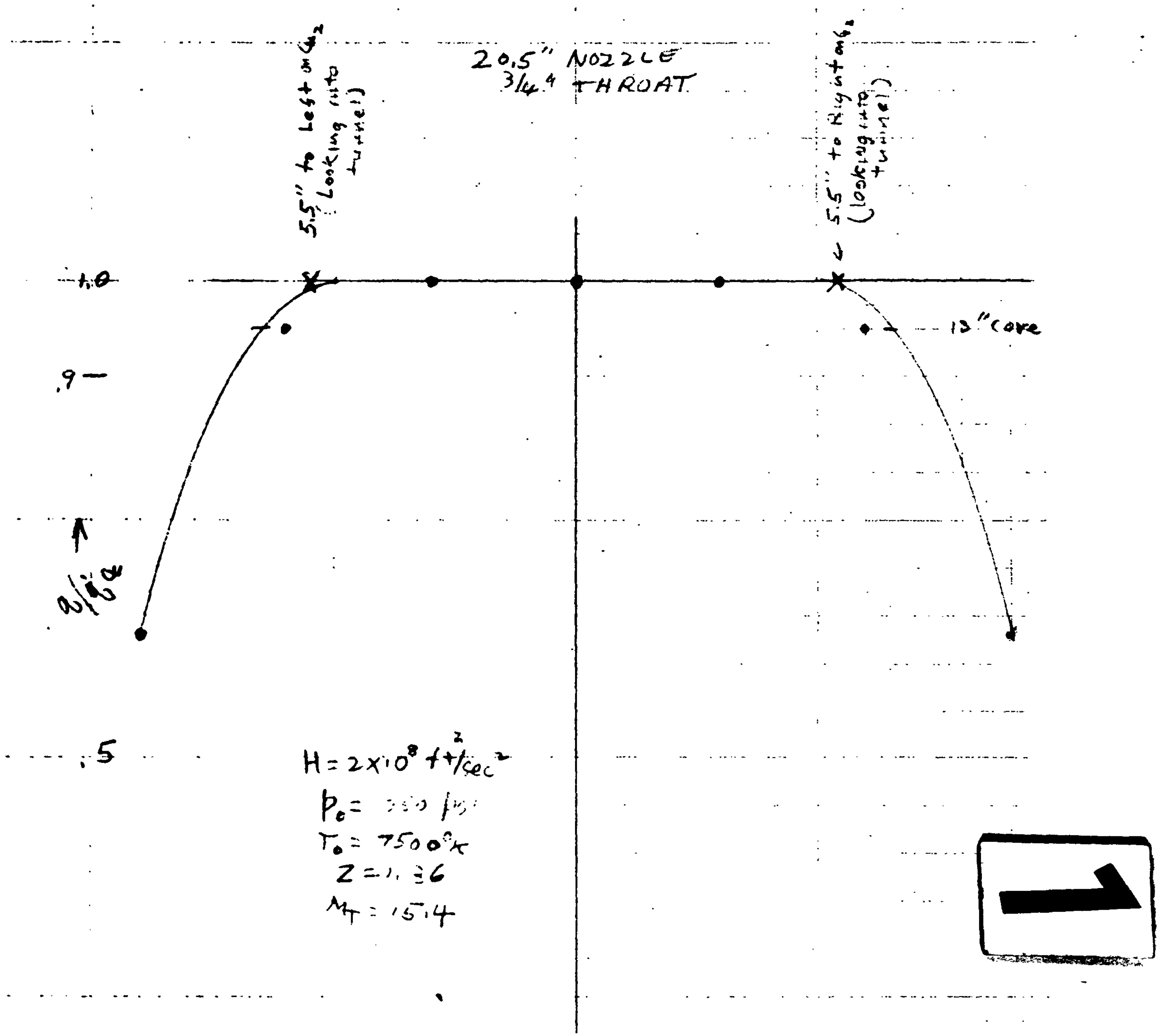
stagnation temperature 7500°K

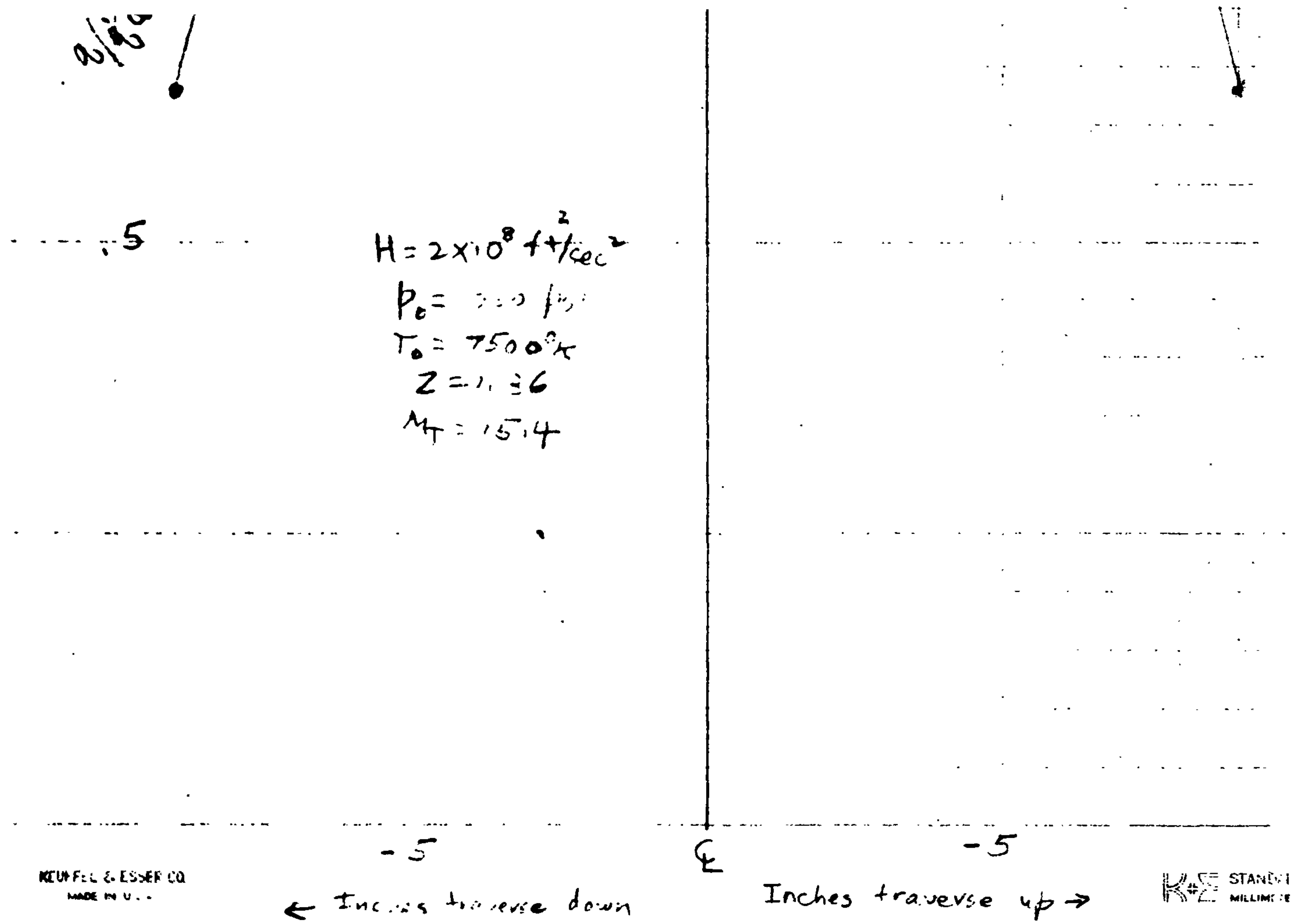
Z 1.36

Mach number 15.4

2

D2.80911
21


20.5" NOZZLE
3/4" THROAT
5.5" to Left of ℄ (Looking into tunnel)
5.5" to Right of ℄ (Looking into tunnel)
13" core
1.0
.9
.5
H = 2×10^8 ft²/sec²
T₀ = 7500°K
Z = 1.36
M_T = 15.4
1



.5
-5
-5
Inches traverse up →
← Inches traverse down
$H = 2 \times 10^8 \ ft/sec^2$
$p_0 =$
$T_0 = 7500°K$
$Z =$
$M_T = 15.4$
KEUFFEL & ESSER CO.
MADE IN U.S.A.
K+E STANDARD MILLIMETER

2

D2-80911
22

THEORY OF PAINT OPERATION

Readout of heat transfer rates are accomplished by means of a series of colors which vary from violet to red through two or three separate changes. These colors are identical in hue and intensity with those obtained from thin films, such as oil slicks on water, and are due to selective interference and reinforcement of various wavelengths present in the white light readout.

The theory of operation of these colors from thin films has been known for three hundred years and is reported in various physics books (Physics, Hausmann, Slack, Second Edition, pages 679-685).

The series of reinforcement colors is given by (normal incidence)* $x = \frac{n\lambda}{4\mu}$, $n = 1, 3, 5 \ldots$

the series of interference colors is given by (normal incidence)* $x = \frac{n\lambda}{4\mu}$ $n = 0, 2, 4, \ldots$

where x is the film thickness in Angstrom units (10^{-8} cm.), and μ is the index of refraction of the film and λ is the light wavelength in Angstrom units.

For a black surface, the n equals zero results in no light reflected.

For a black surface, the n equals one results in no light reflected again due to the lack of interference with the colors not reinforced.

The thinnest film that will appear colored, as explained on page 683 of above reference is the n equals 2 series of interference colors. The first of these colors, corresponding to an interference of violet light is a reddish color produced by the combination of all other colors. This red is not presently picked up due to its faintness, these colors are present in inverse order.

The n equals 3 order of colors is very bright, as the n of 3 order is reinforcing while the n equals 4 order is supressing other colors, and the calibration of this order is seen in the accompanying figure for the equation:

$$1) \quad \frac{\dot{q}}{\dot{q}_{silver}} = 1.30 \times 10^{-3}\left(\frac{n\lambda}{4\mu}\right) - 3.0$$

λ in Angstrom units
$x = \frac{n\lambda}{\text{"}}$ film thickness

1

The theory of operation of these colors from thin films has been known for three hundred years and is reported in various physics books (Physics, Hausmann, Slack, Second Edition, pages 679-685).

The series of reinforcement colors is given by $x = \frac{n\lambda}{4\mu}$, $n = 1, 3, 5 \ldots$ (normal incidence)*

the series of interference colors is given by $x = \frac{n\lambda}{4\mu}$ $n = 0, 2, 4, \ldots$ (normal incidence)*

where x is the film thickness in Angstrom units (10^{-8} cm.), and μ is the index of refraction of the film and λ is the light wavelength in Angstrom units.

For a black surface, the n equals zero results in no light reflected.

For a black surface, the n equals one results in no light reflected again due to the lack of interference with the colors not reinforced.

The thinnest film that will appear colored, as explained on page 683 of above reference is the n equals 2 series of interference colors. The first of these colors, corresponding to an interfernece of violet light is a reddish color produced by the combination of all other colors. This red is not presently picked up due to its faintness, these colors are present in inverse order.

The n equals 3 order of colors is very bright, as the n of 3 order is reinforcing while the n equals 4 order is supressing other colors, and the calibration of this order is seen in the accompanying figure for the equation:

$$1)\quad \frac{\dot{q}}{\dot{q}_{silver}} = 1.30\times10^{-3}\left(\frac{n\lambda}{4\mu}\right) - 3.0$$

λ in Angstrom units
$x = \frac{n\lambda}{4}$ film thickness
$\mu \sim 1$
$n = 3, 5, 7$

The n equals 5 order corresponds to reinforcement also and is also plotted in the color curve. Higher orders of n of 7, 9, etc. overlap each other and produce mixed colors. Partial overlap of n of 3 and 5 also produce different hues in the upper order.

Also plotted in the color curve is the experimental heat transfer and surface temperature obtained in 101 readings by several observers of the paint colors around spheres, using Lee's theory for rate comparision, and square root of the radius rate changes between spheres of different diameters. Standard deviation of 101 readings from equation 1 is plus or minus 8 percent.

The Paint is believed to have the following heat transfer characteristics:

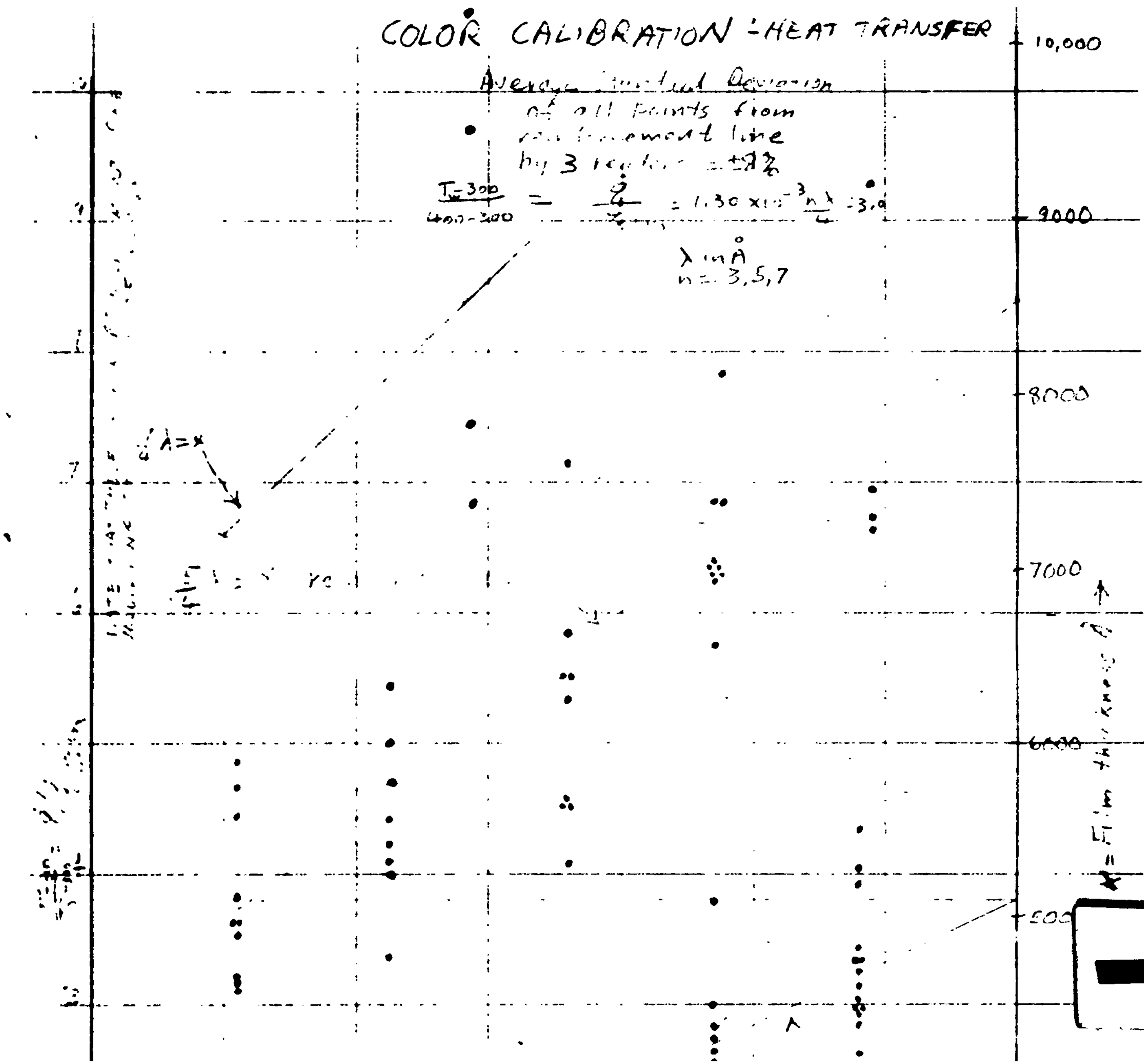
$\mu = 1$ (index of refraction)
C = specific heat = $.37 \frac{cal}{gm\,^\circ K}$
$\rho = 1.2\ gm/cm^3$

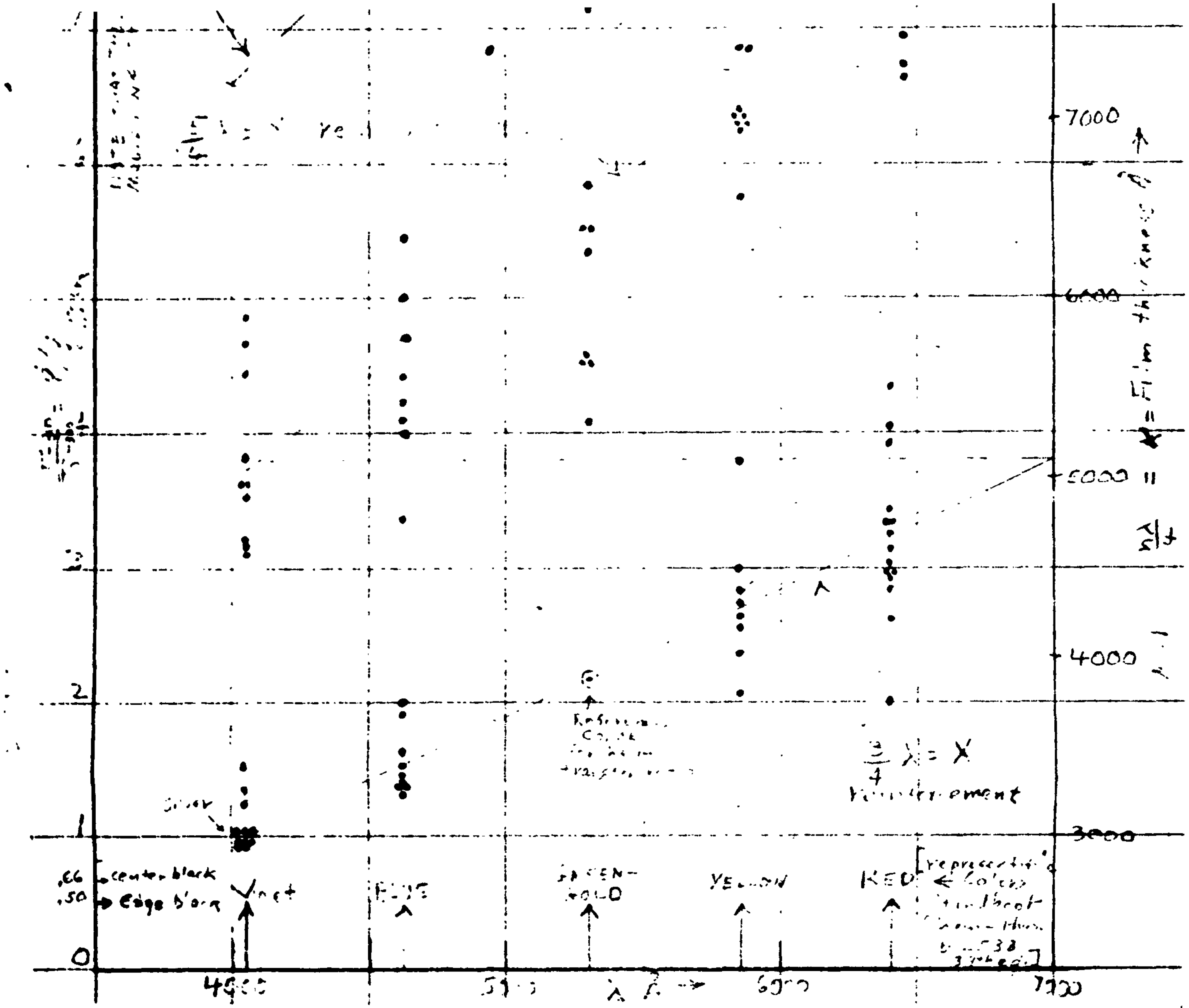
K = heat conductivity = $10^{-3} \rightarrow 10^{-4} \frac{cal}{sec\cdot cm\,^\circ K}$

Use of these characteristics indicates that the wall temperatures for the tests are between 400 and 1600°K, and that the active film is isothermal in nature, i.e. there is very little temperature change across the active film, and the film is behaving like a thin film thermocouple.

it is important that the angle of incidence be kept constant during various rdg.

2


COLOR CALIBRATION - HEAT TRANSFER
Average ... Deviation of all points from ... line by 3 ... = ±?%
λ in Å
n = 3, 5, 7
10,000
9000
8000
7000
6000



7000
6000
5000
4000
3000
2
1
0
.66 center black
.50 Edge b'orn
Silver
Violet
Green-Gold
Yellow
Red
Reference Color
$\frac{3}{4}\lambda = X$
4000
6000
7200

D2-80911
24